THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE

VOL. CXVIII.

LIST OF THE COUNCIL AND OFFICERS

President—BENJAMIN TALBOT.

President-Elect—HENRY LOUIS, M.A., D.Sc.

Past-Presidents

Sir ROBERT HADFIELD, Bt., D.Sc., D.Met., F.R.S.   [LL.D.
Sir HUGH BELL, Bt., C.B., D.C.L., His Grace THE DUKE OF DEVONSHIRE, K.G.
ARTHUR COOPER, LL.D.
The Rt. Hon. LORD INVERNAIRN OF STRATHNAIRN.

C. P. EUGENE SCHNEIDER, Sc.D.
FRANCIS SAMUELSON.
Sir WILLIAM ELLIS, G.B.E., D.Eng.
Sir FREDERICK MILLS, Bt., D.L.
Sir W. PETER RYLANDS, J.P.
FRANK W. HARBORD, C.B.E.

Hon. Treasurer—H. C. H. CARPENTER, Ph.D., F.R.S.

Vice-Presidents

M. MANNABERG.
Col. Sir W. CHARLES WRIGHT, Bt., K.B.E., C.B.
WILLIAM R. LYSAGHT, C.B.E.
GEORGE HATTON, C.B.E.

HARRY BREARLEY.
ALFRED HUTCHINSON, M.A., B.Sc.
ERNEST H. SANITER.
JOHN CRAIG, C.B.E.

Hon. Vice-Presidents

GIORGIO E. FALCK.
PERCY C. GILCHRIST, F.R.S.
ALEXANDRE POURCEL.
CARL A. F. BENEDICKS, Ph.D.
GUSTAVE TRASENSTER.
HENRY LE CHATELIER.
WILLIAM H. HEWLETT.
CHARLES JOHN BAGLEY.

JOHN OLIVER ARNOLD, D.Met., F.R.S.
ILLTYD WILLIAMS.
The Rt. Hon. LORD AIREDALE OF GLEDHOW.
CHARLES M. SCHWAB.
ALFONSO DE CHURRUCA.

Members of Council

WILLIAM SIMONS.
The Hon. R. D. KITSON, D.S.O., M.C.
CECIL H. DESCH, D.Sc., Ph.D., F.R.S.
V. BEARDMORE STEWART, C.B.E.
THOMAS TURNER, M.Sc.
ALEXANDRE DREUX.
JAMES HENDERSON.

ARTHUR DORMAN.
CYRIL E. LLOYD, M.P.
H. SPENCE THOMAS.
WILLIAM H. HATFIELD, D.Met.
MAURICE H. L. BELL, C.M.G.
ALBERT O. PEECH.
WALTER G. GRAY.
EDWARD J. GEORGE.

Honorary Members of Council

P. JUMP (*President of the Staffordshire I. & S. Inst.*).
R. CRICHTON (*President of the West of Scotland I. & S. Inst.*).
H. E. WRIGHT (*President of the Cleveland Inst. of Engineers*).
W. J. BROOKE (*President of the Lincolnshire I. & S. Inst.*).
Sir WILLIAM LARKE, K.B.E. (*Director, Nat. Fed. of I. & S. Manufacturers*).
B. TALBOT (*President, Nat. Fed. of I. & S. Manufacturers*).

Secretary—GEORGE C. LLOYD.

Assistant Secretary—A. E. CHATTIN, B.Sc. (Hons. Met.).

Offices—28 VICTORIA STREET, LONDON, S.W. 1.
Telegraphic Address—"IROSAMENTE, SOWEST, LONDON."
Telephone—"VICTORIA 0853."

PREFACE.

THE present volume of the *Journal of the Iron and Steel Institute* contains the eight papers presented at the Autumn Meeting, held at Bilbao in September 1928, with the discussions and correspondence thereon, to which a report of the visits and excursions to works and mines, made during the meeting, is appended. Section I. concludes with biographical notes of the careers of members deceased during the previous year, published under the heading of Obituary Notices.

Section II. contains the usual notes on the progress of the home and foreign iron and steel industries as reported in the proceedings of scientific and technical societies and in the technical press, together with notices of new books presented to the Institute, and a bibliography of the principal works dealing with the metallurgy of iron and steel and allied subjects which have appeared during the last half-year.

In front of the title page is inserted a list of the British Standardised Steel Samples issued jointly by the Iron and Steel Institute and the National Physical Laboratory, showing where and on what terms the samples are available.

28 VICTORIA STREET, LONDON, S.W. 1.
   December 31, 1928.

CONTENTS.

LIST OF PLATES.

Abbreviations Used in Text.

Å	Ångström unit.	hr.	hour(s).
a.c.	alternating current(s).	in.	inch ; inches.
amp.	ampère(s).	in.-lb.	inch-pound(s).
amp.-hr.	ampère-hour(s).	K.	absolute temperature (scale).
atm.	atmosphere(s) (pressure).	kg.	kilogramme(s).
Bé.	Baumé (scale).	kg.-m.	kilogramme-metre(s).
B.H.P.	brake horse-power.	km.	kilometre(s).
B.O.T.	Board of Trade.	kva.	kilovolt-ampère(s).
B.th.u.	British thermal unit(s).	kw.	kilowatt(s).
B.T.U.	Board of Trade unit(s).	kw.-hr.	kilowatt-hour(s).
B.W.G.	Birmingham wire-gauge.	lb.	pound(s).
C.	centigrade (scale).	L.-F.	low-frequency.
cal.	calory ; calories.	m.	metre(s).
c.c.	cubic centimetre(s).	m.-amp.	milliampère(s).
c.d.	current density.	m.-volt	millivolt(s).
cg.	centigramme(s).	max.	maximum.
c.g.s.	centimetre - gramme - second unit(s).	mg.	milligramme(s).
		min.	minimum ; minute(s).
cm.	centimetre(s).	mm.	millimetre(s).
coeff.	coefficient.	m.m.f.	magnetomotive force(s).
const.	constant(s).	N.	normal (solution).
c.p.	candle-power.	N.T.P.	normal temperature and pressure.
cu.	cubic.		
cwt.	hundredweight(s).	O.-H.	open-hearth; oil-hardened.
d.c.	direct current(s).	oz.	ounce(s).
dg.	decigramme(s).	p.d.	potential difference.
diam.	diameter(s).	R.	Réaumur (scale).
dm.	decimetre(s).	r.p.m.	revolutions per minute.
e.m.f.	electromotive force(s).	sec.	second(s).
F.	Fahrenheit (scale).	sp. gr.	specific gravity.
ft.	foot ; feet.	sq.	square.
ft.-lb.	foot-pound(s).	T.	tempered.
gal.	gallon(s).	temp.	temperature.
grm.	gramme(s).	v.	volt(s).
H.-F.	high-frequency.	va.	volt-ampère(s).
H-ion	hydrogen-ion.	w.-hr.	watt-hour(s).
H.P.	horse-power.	yd.	yard(s).
H.P.-hr.	horse-power-hour(s).	°	degree(s).

SECTION I.

MINUTES OF PROCEEDINGS
AND PAPERS OF
THE IRON AND STEEL INSTITUTE.

AUTUMN MEETING

1928.

Digitized by the Internet Archive
in 2023

MINUTES OF PROCEEDINGS

AND

PAPERS AND DISCUSSIONS

AT THE

BILBAO MEETING,

SEPTEMBER 25–27, 1928.

THE AUTUMN MEETING OF THE IRON AND STEEL INSTITUTE was held in Bilbao, by kind invitation of the members resident in that city and the neighbouring district, under the Presidency of Mr. BENJAMIN TALBOT. The opening ceremony of the General Meeting took place at 10 A.M. in the Assembly Hall at the Alfonso XIII. High School. The Chair was taken by Señor DON CÉSAR BALLARIN, the Civil Governor of the Province of Vizcaya.

Señor DON VALERIANO BALZOLA (Deputy Mayor of Bilbao), at the opening of the proceedings, in a speech in Spanish, welcomed the members and their ladies to Spain.

His Excellency the COUNT DE ZUBIRIA (President of the Reception Committee) said that the first word which, on behalf of his colleagues on the Reception Committee and himself, occurred to his mind on seeing the members gathered at the meeting was " Welcome ! " Spain was not unknown to them, as the residents of Bilbao had had the honour of receiving a visit from the Institute thirty-two years ago. On that occasion so much sympathy was expressed, and such a current of good relations was established, that the members in Bilbao and the surrounding district felt very happy when their invitation to visit Bilbao again was accepted by the Council. The position of President of the Institute had been occupied by men who had transformed the art of the production

of steel, furthering its progress in a truly remarkable way, and in that manner birth had been given to numerous industries of infinite diversity. His colleagues had bestowed upon him the mission of welcoming the members, and that duty he had fulfilled; but he felt it was necessary, although it was not usual to do so in an address of welcome, to give a few figures indicating at a glance the progress made by Spain in the last thirty years.

That progress was evident in every respect, particularly in regard to agriculture, shipping, railways, and trade in general. Roads were now the object of a very big scheme, on which 700 million pesetas were to be spent, with the object of placing Spain, so rich in remembrances of the past, in the forefront of the toured countries. Everything, in a greater or less degree, had made very considerable progress.

To begin with the Budget, its amount at the end of the nineteenth century, when their energies were exhausted and their life paralysed by civil and colonial wars, was 800 million pesetas, but in 1927 it was 3000 million pesetas.

In 1896 there were in existence 18 banks, including the National Bank, with a total paid-up capital of 245,575,000 pesetas. The reserve funds were 10,500,000 pesetas, and deposits and current accounts 1,079,400,000 pesetas. In 1927 the number of banks was 93; the paid-up capital was 957,055,000 pesetas, reserve funds were 390,000,000 pesetas, current accounts 6,500,000,000 pesetas, and deposits had attained to 29,000,000,000 pesetas.

Spain might be considered to be an agricultural country, but nevertheless a large amount of capital was invested in the exploitation of raw materials, coal and iron ore, and their transformation. Some of the works had plants on an imposing scale, bearing in mind the small capacity of absorption of the home market, as well as the diversity of shapes and qualities.

Amongst the 19 existing works, the most important were: Altos Hornos de Vizcaya, Siderurgica del Mediterraneo, Duro-Felguera, Mieres and Nueva Montaña, which owned about a dozen blast-furnaces.

During their visit the members would be able to judge of the importance of the new enlargements and improvements being carried out by the Altos Hornos de Vizcaya, which had cost many millions of pesetas, and they would also be in a position to inspect

the works of the Siderurgica del Mediterraneo, at Sagunto, a completely new plant. He also desired to mention that the Babcock and Wilcox Co. had erected a new engineering works and tube and locomotive factory at Basconia.

Finally, at Reinosa the Sociedad Española de Construcción Naval had established a works for the manufacture of guns, turrets, and ammunition. Those works were of very great importance from the point of view of the manufacture of war material in Spain, and as it had not been possible to include a visit to those works in the programme, he wished to call special attention to them by giving a rapid description of the several plants now in operation.

The foundry shop had three open-hearth and five electric furnaces, the former being devoted to the production of mild steel, and the latter to nickel and chrome-nickel steel for the manufacture of guns, projectiles, moulded and forged castings. In the forge there were two Davy presses of 1000 and 3000 tons, as well as reheating furnaces able to deal with 30-ton ingots. In that shop all kinds of guns and gun parts, ship shafts, crank shafts, &c., were manufactured. There were also the necessary furnaces for heat treatment, provided with apparatus for the automatic control of the temperatures. In the rolling plant there was a 21-in. reversing mill specially constructed for rounds and squares for use in the manufacture of projectiles. At present two new sheet mills were in course of erection which would allow of the manufacture of special sheets for gun-shields.

The artillery shop had four bays served by four electric cranes, and was specially equipped for the manufacture of guns and for speeding up production in case of necessity. The laboratory had all the necessary apparatus for chemical and mechanical tests. All the departments contained the most up-to-date appliances, and the necessary auxiliary shops, electric power plant, &c. Extensions and additions were now being made, and a new stamping press capable of developing 2500 tons pressure was in course of erection, supplementary to the four existing presses.

In the works of the Sociedad Española de Construcción Naval, situated at San Carlos, the company had started preparations for the manufacture of turrets and guns of heavy calibre. In the Sestao Works, belonging to the same company, the manufacture

of submarine Diesel engines was started six years ago, and
14 Diesel engines had already been built with an aggregate power
of 12,800 H.P. Those works also specialised in the manufacture of
reciprocating triple-expansion engines.

The output of coal in 1896 was 1,700,000 tons, and in 1927
6,860,000 tons, and the increase would no doubt have been
greater but for the enormous development of Spanish hydro-
electric resources, which amounted in 1927 to 2,500,000 kw.

The output of iron ore was as follows : 1896, 5,514,329 tons ;
1913, 9,611,668 tons ; 1926, 3,181,000 tons ; 1927, 4,906,000 tons.
The reduction was due to various causes, particularly the state of
things in Spain and the conditions of the foreign markets.

The output of pig iron in 1896 was 297,000 tons, and in 1927
612,000 tons. The output of steel in 1896 was 100,000 tons,
and in 1927, 600,000 tons. The capital invested was 297,357,000
pesetas in shares, and 148,000,000 pesetas in debentures.

Special attention had been paid to shipping. There were at
present 89 companies, with a capital of 400,000,000 pesetas in
shares and 221,000,000 pesetas in debentures.

The gross tonnage in 1896 was 87,415 in sailing ships, and
485,441 in steamers, while in 1928 the corresponding figures were
73,394 and 1,127,037 respectively.

The introduction of electricity in 1901 had played a very
important part in the economics of the country. It had developed
to so great an extent that he was in a position to assert that, with
the actual existing plants and those in course of construction, the
output would exceed 2500 million kw., equivalent to 2500 million
tons of coal. The capital invested in that industry amounted to
1,489,500,000 pesetas in shares, and 1,655,000,000 pesetas in
debentures, a total of 3,144,500,000 pesetas.

Bilbao had always been engaged in shipbuilding, but the
industry was not prosperous until the erection of the Astilleros del
Nervion and the Compañia Euskalduna, which had now extended
their activities to the engineering industry in general and had
produced 79 ships with a total of 143,626 tons, as well as 113 loco-
motives of from 55 to 110 tons, and 1108 wagons and passenger
cars.

In 1908 the Sociedad Española de Construcción Naval came
into being, establishing [yards at Ferrol and Cartagena, as well

as the important works at Reinosa, already referred to. The
principal products of the company were warships, cruisers, sub-
marines and their engines, the total number of ships constructed
being 69, with an aggregate tonnage of 148,423 tons, representing
1,161,255 H.P., a prodigious advance in the productive capacity
of the country.

Besides those constructions of a military character, the com-
pany, desiring to develop merchant shipping, acquired the
Matagorda yards at Cadiz, and established the Sestao yards at
Bilbao. Up to the present, 36 merchant ships had been built,
with a tonnage of 189,058 and 81,183 H.P. As a matter of fact,
the company had built 105 ships, with an aggregate tonnage of
337,483, and a total of 1,242,438 H.P.

The Government had favoured the development of the rail-
ways. New lines had been constructed, and those already exist-
ing had been greatly improved. 1343 million pesetas in shares,
and 2762 million pesetas in debentures were invested in railways.
In 1896 the length of the lines was 11,000 km., and in 1927
17,000 km. The tonnage transported in 1896 was 16,000,000,
and in 1926 42,000,000 tons. The broken and hilly nature of
Spain did not favour the development of the railway network,
and the gradients which were so frequently found were the
principal reason for the moderate speed adopted. The use of
motor-cars had considerably developed, and they competed
strongly with the railways.

In 1898 the wealth of Spain was estimated at 62,000 million
pesetas, while at the present time competent economists estimated
it at 220,300 millions, distributed as follows :

Agriculture	77,000,000,000	pesetas
Cattle	10,200,000,000	,,
Mining	7,000,000,000	,,
City and land wealth	40,000,000,000	,,
Industrial production	48,000,000,000	,,
Railways	5,000,000,000	,,
Shares and debentures of companies (excluding the rail- way, shipping, and mining companies, which are included under their respective headings)	11,000,000,000	,,
Merchant shipping	600,000,000	,,
Public debt	17,000,000,000	,,
Gold and silver	3,000,000,000	,,
Various	1,500,000,000	,,
Total	220,300,000,000	pesetas

The public debts of Spain in 1898 were :

Interior	4,457,687,715	pesetas
Exterior	1,919,468,253	,,
Redeemable 4 per cent.	1,503,635,000	,,
Total . . .	7,880,790,968	pesetas

In April 1928 the debts were as follows :

Interior			5,261,466,115	pesetas
Exterior			911,405,300	,,
Redeemable 4 per cent.			130,827,500	,,
,,	5	,,	1917	964,637,500	,,
,,	5	,,	1920	1,267,040,000	,,
,,	5	,,	1926	225,000,000	,,
,,	5	,,	1927 untaxed . . .	3,546,550,000	,,
,,	5	,,	,, taxed . . .	2,071,400,000	,,
,,	4½	,,	untaxed	500,000,000	,,
,,	4	,,	,, ...	1,098,129,956	,,
,,	3	,,	,, . . .	2,034,347,824	,,
			Total . . .	18,010,804,195	pesetas

The imports and exports in 1896 were : imports 909,589,000 pesetas, exports 1,023,252,000 pesetas ; and in 1926, imports 2,153,521,000 pesetas, exports 1,605,588,000 pesetas.

He did not desire to conclude without mentioning the enormous help given by the Government to the country in different ways, especially by firmly maintaining public order.

He sincerely hoped the stay of the members in Spain would be enjoyable, and he was sure it would prove to be instructive. He trusted that the holding of the meeting of the Institute in Spain would be for the still greater advancement of that country. He was afraid his address of welcome had been rather long, but he hoped he would be excused, bearing in mind that his intention was to give the members an abstract of the progress of the country since their last visit.

Señor Don Alfonso de Churruca (Chairman of the Executive Committee of the Reception Committee) and Señor Don Esteban Bilbao (President of the Provincial Government), speaking in Spanish, also welcomed the delegates.

The President, in reply, said he was sure it would be the desire of the members that he should express their very cordial

thanks to His Excellency Count de Zubiria, Mr. Alfonso de Churruca, and all the members of the Reception Committee, for their kind greetings and for the hospitality which they were extending to them on their visit to Spain. It was thirty-two years since the Institute paid its first visit to that country, and they were pleased to find that the visiting members on the present occasion included among their number four or five of those who were privileged to be present at the meeting of 1896, and who retained the most pleasant recollections of their former visit. Bilbao was an appropriate place for a meeting of that kind, being, as it was, the chief centre of a district where the iron industry had existed from time immemorial. By the Middle Ages the Basque country had become one of the most important iron-producing lands in the world, and in the forges among the hills and valleys there was produced a quality of steel that became famous in all countries. The excellence of the steel weapons exported from Bilbao was attested by the fact that in England, in the days of Shakespeare, the word " bilbo " was a common term for a rapier. The iron from Bilbao was also used for a variety of purposes in our Navy, and in the days of sailing vessels, if a mutinous sailor was put in irons, it was said of him that he was sitting in the " bilboes." In any case, due to the skill of Spanish craftsmen and the excellence of Spanish ores, the direct process, as carried on in the Catalan hearth, yielded a product which was nowhere excelled. Apparently about the height of its prosperity in the eighteenth century, the annual production of the province of Biscay was approximately 20,000 tons of direct iron. When puddling was introduced about the end of the eighteenth century, the industry, he understood, began to suffer from severe competition. He thought Bilbao was a free port, and that the Spanish were free-traders at that time. Owing, however, to the superiority of their products, it would seem that production by the direct method lasted well into the nineteenth century. It was not until 1832 that the first blast-furnace was erected in Spain on the Mediterranean coast, and seventeen years later the first one was built in Biscay. Since then great blast-furnaces, steelworks, and rolling-mills, equipped with every modern device, had been established on the banks of the river Nervion, and the members were looking forward to visiting some of those magnificent plants.

In a few days' time some of the members would also be privileged
to visit another great enterprise—namely, the great new iron and
steel works at Sagunto.

   He desired to say a few words about the wonderful ore resources
of the country, and their relation, not only to English industry,
but to the steel industry of the world. The beginning of the
systematic exploitation of those ores coincided approximately
with the rise of the Bessemer process.   By 1870 some 200,000 tons
of ore were being exported annually, nearly all to Great Britain.
Unfortunately, the Civil War, which afflicted the country from
1873 to 1876, caused a complete stoppage of the exports, but after
that the development went on apace, and by 1878 the exports
from Bilbao to Great Britain were 903,000 tons.   It was in that
decade that Bessemer steel rails were introduced, and, due to
the great railway developments of that period, the demand for
Bessemer rails increased so rapidly that unless they had been
able to obtain an ample supply of the very pure ores from Bilbao
it would have been impossible to keep pace with that demand.
The earliest recorded figures of the production of Bessemer steel
rails was 620,000 tons in 1875.   By 1880 it was 1,044,000 tons,
and in 1890 the production of steel rails in Great Britain had
reached 1,720,000 tons.   In the paper which Mr. Balzola had
kindly prepared for the meeting, it was stated that the total
quantity of ore already extracted in the Bilbao district since
mining operations began was 200,000,000 tons.   Practically the
whole of that vast quantity of ore had been utilised in the
production of steel, and it represented, therefore, an enormous
contribution to the development of the world.   The total amount
of steel produced from that ore must be more than equal to the
world's production of steel in 1927, which was 90,011,000 tons.
Those figures gave some idea of the tremendous debt which the
world owed to the district of Bilbao as a productive source of iron
ore.   From 1900 onwards the production and exports of iron ore
from Bilbao, as everybody knew, had greatly declined, owing to
the approaching exhaustion of some of the better mines.   But
notwithstanding those conditions, the prosperity of Bilbao had
by no means declined, and there had sprung up a number of new
prosperous manufacturing industries, for the maintenance and
conduct of which the local conditions were well adapted, which

circumstance was a just cause for unbounded admiration of the energy and enterprise of its citizens.

He asked their hosts once more to accept their very hearty thanks for their kind words of welcome and their hospitable reception.

The CHAIRMAN (the Civil Governor of the Province) (speaking in Spanish) also welcomed the delegates.

The Chair was then vacated by the Civil Governor, and for the remainder of the meeting Mr. Benjamin Talbot, the President, presided.

The PRESIDENT said it was his privilege to announce that Professor Henry Louis had been nominated for election as President for the following year.

BALLOT FOR ELECTION OF NEW MEMBERS.

The scrutineers of the ballot for the election of new members announced that the following fifty-four candidates for membership, and one candidate for associateship, had been duly elected.

MEMBERS.

NAME.	ADDRESS.	PROPOSERS.
Arboledas, Juan S. .	Siderurgica del Mediterraneo, Sagunto-Valencia, Spain	E. Coste, J. Roure, E. Aburto.
Bailey, Francis James, M.Sc., D.I.C.	National Federation of Iron and Steel Manufacturers, Caxton House (East), Tothill Street, London, S.W. 1	Sir Wm. Larke, K.B.E., M. S. Birkett, E. C. Evans.
Balzola, José . .	Apartado 42, Bilbao, Spain	L. Barreiro, E. Coste, J. Roure.
Barbaro, Louis E. .	Locomotive, Carriage and Wagon Department, Burma Railways Workshop, Insein, Lower Burma	F. W. Harbord, C.B.E., V. Harbord, B. Talbot.
Beale, Sir John Field .	Chairman, Orconera Iron Ore Co., Ltd.	B. Talbot, W. Simons, E. J. George.

NAME.	ADDRESS.	PROPOSERS.
Budd, Leonard William	C/o La Compañía Petrolera Lobitos, Lobitos, Via Talara, Peru	F. W. Harbord, C.B.E., V. Harbord, B. Talbot.
Cameron, Charles Symonds	C/o British Empire Steel Corporation, Ltd., Canada Cement Building, Phillip Square, Montreal, Canada	F. W. Harbord, C.B.E., B. Talbot, E. F. Law.
Carretero, Luis . .	Avenida del Padre Isla 2, León, Spain	J. Perez Salado, V. Balanzategui, L. Barreiro.
Cochran, Ralf Smyth, A.B., Met.E.	Surface Combustion Co., 2375 Dorr Street, Toledo, Ohio, U.S.A.	R. J. Cowan, C. W. Weesner, G. A. Reinhardt.
Cunningham, James, Wh.Sch.	68 Clarkegrove Road, Sheffield	W. H. Hatfield, A. Matthews, J. W. Fawcett.
Daeves, *Dr.-Ing.* Karl.	Vereinigte Stahlwerke A.G., Breitestr. 69, Düsseldorf, Germany	E. Schrödter, H. Reuter, H. C. H. Carpenter, F.R.S.
Day, Charles Roy .	136 Derby Road, Sunshine, Victoria, Australia	J. N. Greenwood, P. L. Martyn, E. Lewis.
Elgood, William Nelson	C/o Messrs. Thos. Cook & Sons, Berkeley Street, London, W. 1	F. W. Harbord, C.B.E., W. S. Gifford, R. G. Lyttelton.
Estep, Frank L. . .	11 West 42nd Street, New York, U.S.A.	A. de Churruca, J. Roure, L. Barreiro.
Farrell, James Augustine	Room 1817, 71 Broadway, New York, U.S.A.	B. Talbot, B. Walmsley, R. F. Gurney.
George, Frank Bernard, B.Sc. Mech.	13 St. Cuthbert's Terrace, Blackhill, Co. Durham	A. Hutchinson, W. Firth, J. H. Whiteley.
Graham, H. W. . .	The Jones and Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A.	J. Hall, C. F. L. Mace, J. A. Hopkinson.
Hale, James Stanley .	Principe 4, Bilbao, Spain	G. Watson Gray, W. H. Pearson, L. Barreiro.
Heppenstall, Charles William	Heppenstall Forge and Knife Co., Pittsburgh, Pa., U.S.A.	B. D. Saklatwalla, G. L. Norris, F. Garratt.
Hughes, Harold Lincoln	71 Broadway, New York, U.S.A.	B. Talbot, B. Walmsley, R. F. Gurney.
Huston, J. Stewart .	64 S. 1st Avenue, Coatesville, Pa., U.S.A.	B. Talbot, M. J. Conway, F. W. Harbord, C.B.E.
Johnson, Hjalmar William	6748 East End Avenue, Chicago, Ill., U.S.A.	J. A. Mathews, B. Stoughton, D. A. Lyon.
Johnston, John, D.Sc.	U.S. Steel Corporation, 71 Broadway, New York, U.S.A.	B. Talbot, B. Walmsley, R. F. Gurney.
Kinney, Selwyne Perez	U.S. Bureau of Mines, Minneapolis, Minn., U.S.A.	J. A. Mathews, B. Stoughton, D. A. Lyon.
Kjellberg, Carl J. .	Apartado 769, Paseo de Gracia 20, Barcelona, Spain	A. Wahlberg, C. Benedicks, A. Johansson.

NAME.	ADDRESS.	PROPOSERS.
Levy, Lawrence . .	22 Bracknell Gardens, London, N.W. 3	Sir W. Charles Wright, Bt., I. F. L. Elliot, H. B. Jacks.
McNaught, Charles Boyd	British Empire Steel Corporation, Ltd., Canada Cement Building, Phillip Square, Montreal, Canada	F. W. Harbord, C.B.E., B. Talbot, E. F. Law.
Marsh, Lawrence S. .	38 S. Dearborn Street, Room 1157, Chicago, Ill., U.S.A.	H. P. Tiemann, F. G. Blackburn, C. F. W. Rys.
Mason, Charles Lyall .	Kenwood, Sheffield	A. Good, H. C. Loving, J. B. Allan.
Maurer, *Prof. Dr.-Ing.* Edward	Eisenhütten-Institut der Sächs. Bergakademie, Freiberg - i. - Sa., Germany	E. Schrödter, B. Talbot, H. C. H. Carpenter, F.R.S.
Otto, *Dr.-Ing.* Carl .	Dr. Otto & Co., Bochum, Germany	W. F. Cheesewright, W. Hiby, V. B. Reichwald.
Paton, N. Anderson .	Apartado 908, Barcelona, Spain	A. de Churruca, J. Roure, L. Barreiro.
Pease, Claud Edward .	92 Northgate, Darlington	B. Talbot, F. W. Harbord, C.B.E., F. Samuelson.
Pièrard, Paul . .	9 Boulevard Pèreire, Paris (17ᵉ)	L. Guillet, A. M. Portevin, E. L. Dupuy.
Rao, P. Krishna .	Superintendent of Foundries, Mysore Iron Works, Bhadravati, Mysore, India	D. F. Campbell, H. M. S. Tuckwell, F. W. Harbord, C.B.E., W. S. Gifford.
Ross, David . .	Rivington, Eaglescliffe, Co. Durham	B. Talbot, A. N. McQuistan, F. W. Harbord, C.B.E.
Scott, William Wallace, jun.	Laclede Steel Co., St. Louis, Mo., U.S.A.	H. P. Tiemann, J. S. Unger, F. G. Blackburn.
Sohn, Erwin . .	C/o Standard Sanitary Manufacturing Company, 2801 Preble Avenue, Northside, Pittsburgh, Pa., U.S.A.	J. Aston, B. Talbot, F. W. Harbord, C.B.E.
Steiner, Otto Ferdinand	64 Victoria Street, London, S.W. 1	F. W. Harbord, C.B.E., E. F. Law, B. Talbot.
Stevenson, Thomas .	National Federation of Iron and Steel Manufacturers, Caxton House (East), Tothill Street, London, S.W. 1	Sir Wm. Larke, K.B.E., M. S. Birkett, E. C. Evans.
Stratford, William George Henry	C/o Compañía Petrolera Lobitos, Lobitos, Via Talara, Peru, S. America	W. H. Poole, F. W. Harbord, C.B.E., V. Harbord.
Succop, John A. .	Heppenstall Forge and Knife Co., Pittsburgh, Pa., U.S.A.	B. D. Saklatwalla, G. L. Norris, F. Garratt.

NAME.	ADDRESS.	PROPOSERS.
Sullivan, William James	U.S. Steel Corporation, Room 1817, 71 Broadway, New York, U.S.A.	B. Talbot, B. Walmsley, R. F. Gurney.
Taverner, Leonard, Assoc.R.S.M., M.I.M.M.	University College, Swansea	H. C. H. Carpenter, F.R.S., C. A. Edwards, C. O. Bannister.
Taylor, Thomas Edwards	36 New Broad Street, London, E.C. 2	B. Talbot, J. E. James, W. A. Caddick.
Taylor, Thomas Lester Addy	36 New Broad Street, London, E.C. 2	B. Talbot, J. E. James, W. A. Caddick.
Thompson, Robert Chester	Carnegie Steel Co., Mingo Junction, Ohio, U.S.A.	H. P. Tiemann, F. G. Blackburn, C. F. W. Rys.
Torres, Ary Frederico .	Escola Polytechnica, S. Paulo, Brazil	A. Hethey, H. C. H. Carpenter, F.R.S., W. H. Hatfield.
Vessey, John Oliver .	" Green Lawn," Coal Aston, Sheffield	A. R. Habershon, T. P. Colclough, A. Allison.
Warren, William H. .	Greenwood Apartments, Coatesville, Pa., U.S.A.	B. Talbot, F. F. Foss, M. J. Conway.
Watson, Ralph H. .	Munhall, Pa., U.S.A.	C. F. W. Rys, H. P. Tiemann, F. G. Blackburn.
White, George Arthur.	" Donaghdee," Scunthorpe, Lincolnshire	C. T. Thomas, K. T. Thomas, M. R. Tinsley.
Wood, Percy Wyatt	The Bungalow, Consett, Co. Durham	E. J. George, W. Firth, J. H. Whiteley.
Yokoyama, Taketo .	Kobe College of Engineering, Kobe, Japan	C. A. Edwards, H. C. H. Carpenter, F.R.S., L. B. Pfeil.

ASSOCIATE.

Clasen, Andrew Joseph	77 Addison Road, London, W. 14	A. Meyer, H. C. H. Carpenter, F.R.S., B. Clasen.

RESOLUTION OF CONDOLENCE.

The PRESIDENT, at the opening of the meeting on Wednesday afternoon, September 26, said he was sure the members would desire, as the first business of the meeting, to pass a resolution of condolence with those who had suffered in consequence of the disaster connected with the theatre fire in Madrid. A telegram had been sent to the Spanish Government expressing the condolences of the Institute.

All present stood in silence while the resolution was passed.

Retirement of Vice-Presidents and Members of Council.

The Secretary submitted, in accordance with Rule 10, the following list of Vice-Presidents and Members of Council due to retire at the Annual Meeting in 1929. *Vice-Presidents :* Mr. E. H. Saniter, Colonel Sir Charles Wright, Bt., K.B.E., C.B., and Mr. Mannaberg. *Members of Council :* Mr. Arthur Dorman, Dr. W. H. Hatfield, D.Met., Mr. V. Beardmore Stewart, C.B.E., Mr. H. Spence Thomas, and Mr. A. O. Peech.

Election of New Honorary Member.

The President said he was sure all the members would be delighted to hear that the Council had elected the Count de Zubiria as one of the Honorary Members of the Institute. He thoroughly deserved the honour, not because of the long period of time he had been a member of the Institute, but because of the work he had done for the advancement of the industry.

The following papers were presented :

J. Balzola : " Iron Ore Mining in Vizcaya."
A. Herrero and M. de Zubiria : " The Phenomena of Corrosion of Iron and Steel."
J. Orland : " The Influence of Pearlitisation below the A_1 Point on the Mechanical Properties of Carbon Steels."
J. G. Pearce : " The Use and Interpretation of the Transverse Test for Cast Iron."
C. A. Edwards and T. Yokoyama : " The Influence of Varying Strains and Annealing Temperatures on the Growth of Ferrite Crystals in Mild Steel."
L. B. Pfeil : " The Change in Tensile Strength due to Ageing of Cold-Drawn Iron and Steel."
S. H. Rees : " Some Properties of Cold-Drawn and of Heat-Treated Steel Wire."
J. H. Whiteley : " Effects Observed in Quenched Liquid Steel Pellets and their Bearing on Bath Conditions."

Votes of Thanks.

The President said that in closing the proceedings he begged formally, although very cordially, to propose that a very hearty vote of thanks be accorded :

" To His Excellency the Count de Zubiria, the President, and all the Members of the Reception Committee ; likewise to Her Excellency

the Countess de Zubiria, Chairman of the Ladies' Committee, for their warm welcome and hospitable reception of the members and their ladies during the days of their meeting in Bilbao.

" To Señor Don Iltmo. Alfonso de Churruca, President, Señor Don Iltmo. Luis Barreiro, Hon. Secretary, and the other Members of the Executive Committee, for all the arrangements so carefully planned and admirably carried out for the entertainment, comfort, and convenience of the members throughout the days of their stay in San Sebastian and Bilbao and other cities in Spain. In that connection thanks had also to be accorded to Señor Don José de Orueta of San Sebastian, and to General Gomez Nuñez of Madrid, Chairmen of the Sub-Committees in those cities.

" To His Honour the Lord President and the Council of the Province of Vizcaya, and to His Honour the Lord President and the Council of the Province of Guipuzcoa, for their hospitable reception and kind patronage and support of the meeting.

" To His Excellency the Alcalde and the Municipal Authorities of Bilbao, and to His Excellency the Alcalde and the Municipal Authorities of San Sebastian, for their kind and hospitable reception and entertainment in those cities.

" To the Mining and Metallurgical Companies of Vizcaya and at Sagunto, for permission to visit their respective Mines and Works, and for their most generous hospitality in entertaining the members and their ladies at the various festivities and excursions.

" To the Directors of the Alfonso XIII. High School, for their kind permission to use their magnificent hall for the purposes of the meeting.

" Finally, the members desired to express their best thanks to Señor Don Emilio Coste, for the preparation of the beautiful and instructive handbook which had been placed in the hands of the members and would form an interesting memento of the meeting."

Mr. F. W. HARBORD, C.B.E., formally seconded the motion, which was carried by acclamation, and the meeting then terminated.

ADJOURNED MEETING AT BIRMINGHAM.

The papers by J. G. Pearce, L. B. Pfeil, and S. H. Rees, mentioned above (p. 13), were discussed at an Adjourned Meeting held under the Chairmanship of Mr. GEORGE HATTON, C.B.E. (Vice-President), at the Engineers' Club, Birmingham, on October 25, at 4 P.M. ; about fifty members and friends were present. The meeting adjourned for tea at 5 P.M., and terminated at 7.30 P.M.

IRON ORE MINING IN VIZCAYA.[1]

By JOSÉ BALZOLA, Mining Engineer
(Bilbao, Spain).

On the occasion of the Institute's last visit to Bilbao in 1896, the late Mr. William Gill, then Resident Manager of the Orconera Iron Ore Company, at the request of the Council prepared an extensive and detailed paper descriptive of the mining district, its position, and prospects. My task to-day, in responding to a like request, is to a great extent the simpler one of bringing Mr. Gill's paper up to date. In doing so it will be necessary to repeat some of the information already contained in that paper.

The surface of Vizcaya consists principally of rocks of the Cretaceous period. There is a belt of Eocene formation from Ermua to Sopelana, composed of sandstone and alternate beds of limestone and marl. Volcanic traces appear in several places in the province as outcrops of ophate and trachyte, principally the former. These outcrops do not break the Eocene series.

The mineralised zone is represented by a bed of a fossil-bearing limestone of the Aptens period, the fossils being of marine origin, principally corals, requenias, and ostreas. The ore replaces this limestone at times completely, at others partially or not at all. This limestone or ore, when not uncovered, lies between two beds of a micaceous shale, which varies from a true psammite to a shaly sandstone. The upper shale bed corresponds to the Albense period, and in it are found some ammonites. The upper and lower beds are hardly distinguishable from one another, the lack of fossils generally not aiding in their differentiation.

Between the fossil-bearing limestone and the upper shale, and easily distinguishable from the former, is sometimes found a shaly limestone, appearing invariably in layers with a decided tendency

---

[1] Received July 20, 1928.

to weather into black clay. One finds again, within the upper
shale, a lamina of limestone which differs considerably from either
of the limestones mentioned. Above the shale begins the upper
Cretaceous, composed of alternate beds of marl and shale.

The Bilbao ore deposit is on a wide anticlinal fold, the axis
of which, running NW.–SE., is denuded, showing bare the lower
shale. The strata dipping SW. is represented by the Galdames
group of mines, that dipping NE. by the Triano and Matamoros
mines. The deposit extends SE. through Bilbao as far as San
Miguel de Basauri, and NW. to the province of Santander by
Setares and Dicido, some 24 km. long by 6 km. wide.

The district is cut by numerous faults, some with throws of
60 or more metres. These may be divided into two groups. The
newer or longitudinal faults follow a fairly regular and parallel
NW.–SE. direction, and were undoubtedly formed by the orogenic
movement which folded the strata. They cut the older or cross
faults, which vary considerably in direction. Mineralisation has
been produced after the faulting by hydrothermal springs, which,
saturated with carbonic acid and charged with ferrous carbonate,
resulted in the replacement of the limestone by the latter, and
formed carbonate of iron or spathic ore.

An indication, as pointed out by Don Ramon de Yarza, that
the faulting preceded the hydrothermal action is the invariably
upright position of the unmineralised limestone peaks in the ore
mass. The springs probably bear some relation to the volcanic
rocks already mentioned. These can be seen in Ollargan, San
Luis, and Abandonada following a direction parallel to the
longitudinal faults.

The intensity of the mineralisation bears a relationship to that
of the fissures caused by the faults, and so the ore bed follows the
longitudinal faults, and has its maximum importance at the junc-
tion of these with the cross faults. The thickness of the ore-
limestone bed varies between 90 and 30 m., having been mineralised
in places to a potency of a million tons per hectare, as in Parcocha
and Concha 1. Fig. 1 is a geological section of the Concha 2[A]
mine.

Spathic ore has a density of $2 \cdot 8$ to 3 ; it appears in two classes,
" grey " and " white." " Grey " spathic is the primary ore, and
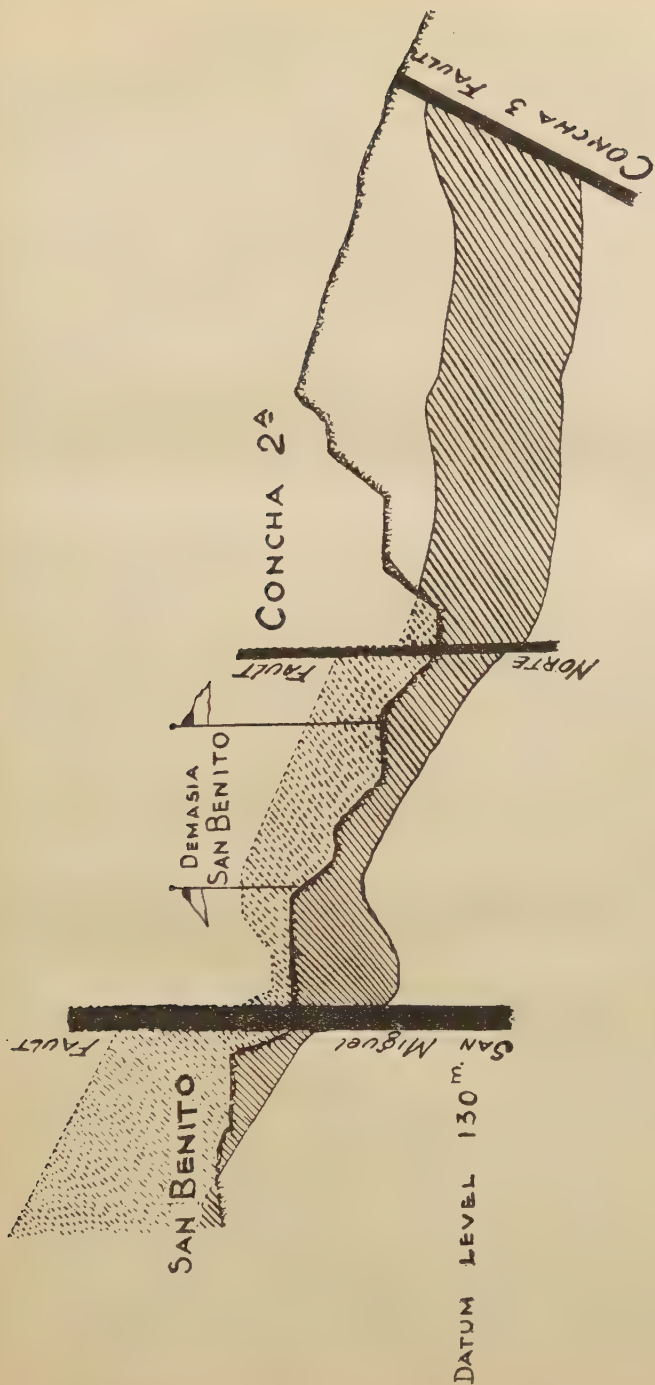is composed of small grey and white granules, harder and more

Fig. 1.—Geological Section through Concha 2ᴬ Mine.

Concessions of mines are made by *pertenencias*, or squares of 100 × 100 m. *Demasía* is a surplus concession, granted to one of the surrounding mines, of a space between two or more *pertenencias* into which a full *pertenencia* cannot be fitted.

siliceous and higher in sulphur than the " white." " White " spathic ore is creamy-white, composed of crystals of siderite derived from the " grey " spathic by a process of solution and crystallisation. It disintegrates more easily on calcination than does the " grey." Spathic ore is bespattered with tiny crystals of iron pyrites, which render the ore high in sulphur. The actual production of spathic is roughly $\frac{1}{3}$ of the total output.

The more common oxide of iron is rubio, a hydrated ferric oxide, brown hematite or limonite, derived from the oxidation of the carbonate. It has a density of from 2 to 2·5, and occurs in cellular or concreted forms. The oxidation has commenced on the periphery and has continued inwards, as can be seen by the nucleus of spathic still remaining in many blocks of the ore.

The pyrites contained in the carbonate generally remains free in the space between the rubio crust and the nucleus. A further stage of the process is the complete oxidation of the spathic, and it is to be observed that the pyrites concentrates in the cavity formed (locally called *olla*), or is washed away partially by the weathering water. The water of crystallisation is on an average 10·58 per cent., except in the inner part of the *olla*, in which the ore takes on a steely appearance, when it sinks to as low as 4 per cent., and the ore is therefore no longer a true limonite.

Vena and campanil are red hematites, both, like rubio, derived from the oxidation of the carbonate. Vena is a soft purple compact or powdery mineral, the purest of the Vizcaya ores, and that originally used exclusively in the old Catalan forges of the country. Campanil is an epigenesis of the white spathic ore, and is compact and crystalline. Its name is derived from the bell-like sound (*campana*) emitted when it is struck with a hammer. The composition of the gangue of campanil is nearly self-fluxing, and this property, combined with its easy reduction, makes the ore ideal for the Bessemer process. Both vena and campanil are fast becoming extinct, particularly the former. Their production is restricted to a few mines, and does not exceed 100,000 tons per annum.

Chirta is a gravel-like ore, composed of concretions or nodules of red or brown hematite surrounded by clay. The name has been extended to clays now loaded from old rubbish tips for washing purposes.

Table I. shows typical analyses of ores in the Bilbao district.

TABLE I.—*Analyses of Vizcaya Ores.*

	First-Class Rubio.	Second-Class Rubio.	Campanil.	First-Class Calcined Spathic.	Second-Class Calcined Spathic.
	%	%	%	%	%
Ferrous oxide .	...	...	...	1·00	0·52
Ferric oxide . .	77·479	70·710	84·00	81·62	71·39
Silica . . .	9·18	16·40	3·20	9·03	17·00
Alumina . .	1·76	1·89	...	1·37	2·70
Manganese oxide .	1·11	0·77	1·90	1·39	3·50
Lime . . .	0·10	0·45	4·60	1·39	3·50
Sulphuric acid .	...	0·32	...	...	1·07
Sulphur .	0·055	...	...	0·426	...
Phosphoric acid :	0·052	0·078	Trace	0·032	0·032
Loss on calcination .	10·00	4·00	6·30	1·90	0·67

The averages for first-class rubio and spathic ores are :

	%		%
Moisture . .	8·20		2·19
Iron, dry . .	53·95		58·70
Iron, moist . .	49·53		57·42
Silica . . .	10·26		7·97
Sulphur . .	0·028		0·368
Phosphorus . .	0·017		0·007

The moisture varies considerably with the weather.

Working.—The majority of the mines are worked in opencast, with benches 20 to 30 m. in height, which are connected by railways or inclined planes. The explosive in general use is dynamite No. 3, of the following composition :

				Per cent.
Nitro-glycerine	.	.	.	22·50
Sodium nitrate	.	.	.	65·52
Coal . .	.	.	.	11·98

Less used is the so-called " Goma No. 2," of the following composition :

				Per cent.
Nitro-glycerine	.	.	.	37·50
Nitro-cellulose	.	.	.	2·25
Ammonium nitrate		.	.	18·00
Sodium nitrate	.	.	.	29·25
Flour . .	.	.	.	13·00

The dynamites are sold in boxes of 25 kg., each box containing 10 packets of 2·5 kg. with some 30 cartridges to a packet, 22 mm.

in diameter and 130 mm. in length. The No. 3 dynamite is well adapted to the softer rocks, such as shale, limestone, and rubio. " Goma No. 2," because of its shattering effect, is more effective in the harder spathic and *gabarro* (hard siliceous shale).

Drilling is done either by hand or by compressed air. In hand-drilling jumpers are used, and holes are classified as " one-handed," " two-handed," or " three-handed," according to the number of drillers employed.   " One-handed " holes are employed for block-holing or secondary blasting, and sometimes in the quarry face when the rock is favourably located. " Two-handed " and " three-handed " holes are used in the quarry face, and are always nearly vertically downward holes. The holes are begun by the first jumper, which is 2·5 m. long and 25 mm. in diameter, with a cutting edge of 40 to 44 mm. ; the jumpers are changed every 1·5 m.

Compressed air for drilling has been introduced into a great many of the mines. The favourite tool is the " hammer-drill " of 12 to 20 kg., served generally by two drillers. The men of the district are skilful in the use of hammer-drills, and it is general practice to drill holes 6 to 6·5 m. long with these small hammers.

The change of steel is made each 60 cm., beginning with a diameter of 40 to 42 mm. and ending with 22 mm. The structure of the rubio ore is not well adapted to the use of ordinary hammer-drills, and in some places drills are used for all rocks except rubio.

The work done in an eight-hour shift by a good driller in a one-handed hole is approximately as follows :

Shale	6·00 m.
Limestone	5·50 m.
Rubio	Very variable
Gabarro	0·30–0·45 m.
Spathic	2·50–3·50 m.

The average cost is about 2·50 pesetas per m.

The drilling speed of a hammer-drill is, in average rock on a 5 to 6 m. hole, about 0·9 dm. per minute. Making a liberal allowance for stoppages and delays, its capacity can be taken as about 24 m. per shift, at a cost of 27·50 pesetas (including plant amortisation), or, say, 1·15 pesetas per m.

Blasting.—After drilling the hole a chamber is blasted at its

extremity to concentrate the charge of explosives.   The following
is an example of dynamite used in chambering a spathic hole :

First	3 cartridges,	219 grm.	of dynamite No. 3
Second 6	,,	438 ,,	,, ,,
Third 12	,,	876 ,,	,, ,,

and so on.

Blasting is not done according to any set rules, but follows the
judgment of the foreman, who determines the position of the hole
and the charge.   It is carried out at lunch time and at the end
of the day's work.   Fuses and caps are in general use ; more rarely
electric firing is utilised in some workings, particularly under-
ground.   The cost of No. 3 dynamite at the mines is 3·80 pesetas
per kg., including 0·80 peseta tax.   " Goma No. 2 " costs
5·75 pesetas per kg., including 1·25 pesetas tax.

Holes are generally marked, not so much with a view of
breaking the ore to a suitable size for loading, but rather of
making the largest volume with a minimum of explosive.   This
involves a great amount of secondary blasting.   Sometimes the
amount of explosive used in the secondary blasting reaches ten
times that of the main charge.   Formerly, higher working faces
were allowed, with the consequent necessity of more secondary
blasting.   In early times a shot of 3000 tons was usual ; to-day
shots of 500 tons are considered large.   The following figures give
an idea of the amount of explosive used :

	Spathic.	Rubio.	Shale.	Limestone.
Charge (grm. per cu. m.) .	300	100–300	100–150	200
Chambering (per cent.) .	25	25	15	20
Secondary blasting (per cent.) .	60	50	60	50

Loading of Wagons.—Once the rock has been blasted to about
0·5 m. size, when it is no longer economical to use explosive, it is
broken by hammer to the necessary dimensions for classification
and shipment.   No mechanical crushers are used yet, but in the
general trend towards mechanisation it is more than possible that
they will soon be introduced.   In a spathic quarry, for example,
20 per cent. of the loading men are employed breaking stones.

The tools generally used for loading are primitive—hoes, rakes,
and baskets.   The hand-shovel is not employed.   The waste of
baskets is very high.   In winter a basket may last as little as
one day.   On an average the life is six days, and the cost is

1·25 pesetas each—this makes a basket charge of 3 to 4 centimos per cu. m., but as a complicated sorting is necessary before loading, it meets the purpose fairly well.

The full basket weighs 22 to 27 kg.   The yield per loader varies from 8·5 to 5 cu. m. in the eight-hour shift, according to the height of the wagon and the distance between the face and the wagon.

The wagons used vary in capacity from 0·5 to 3·5 cu. m., more generally 1·5 to 2·5 cu. m.   To facilitate loading a platform is provisionally left unexcavated next to the wagon.   The yield per man and explosives is lower by 20 to 30 per cent. than that in ordinary quarry work in recovering this platform.   In places where there is no classification, such as overburden, the " glory-hole " method is sometimes practised.   Production is then much greater, reaching occasionally a total of 25 cu. m. per man.   The volume yield per loader is not much affected by the density of the different kinds of ores and rocks, the sorting being the principal factor.   This is due to the fact that the lighter materials are sticky, while the heavier are not.

Of late years power shovels have been coming into general use. The first to use shovels in the district was the Orconera Company in the early '90's for the overburden of Orconera 5.   This attempt was not successful, and the shovel was abandoned, but at that time labour was very cheap [1] and the steam shovel was in its infancy. To-day circumstances have altered.   Shovels are stronger, more reliable, and much perfected, and labour is paid 7 to 7·5 pesetas for the legal shift of eight hours, as against 3·75 to 3 pesetas formerly for the ten-hour shift.

Several years ago the Dicido Company installed at its mine in the province of Santander the Bucyrus 2½ yards dipper railway-type " C " shovels.   Each shovel is served by small steam loco-motives, and the distance between the face and the tips is very small, 300 to 600 m.   The production of this shovel is about 500 to 600 cu. m., reaching sometimes 1000 cu. m.   The benches are very high, as can be seen in the accompanying photographs (Plate VII.), and the overburden is blasted down before loading begins.   These shovels are very rapid in their movements, taking an average of 25 seconds for a complete dipper swing.

In the Vizcaya mines small shovels are now being used with great

[1] See Gill's paper, *Journal of the Iron and Steel Institute*, 1896, No. II. p. 36.

economic advantage, both in the Bilbao and Orconera mines, on overburden and on the reworking of old tips for washing purposes. The wider applicability of mechanical loading is at present merely a problem of classification and picking, the importance of which is self-evident where ore is concerned. In the case of old rubbish tips worked for washing purposes, the importance of sorting is dependent on the length of transport to the washery, abundance and cost of water, settling marsh, and dumping ground, and these factors are decisive in methods of loading. The Orconera Company has recently had highly satisfactory and efficient results in experiments with belts in combination with steam shovels.

A comparison of the cost of loading with mechanical shovels and hand-loading is given in Fig. 17 (p. 47), and the working details are as follows :

						Per cent.
Working time	.	.	.	.	.	68·13
Time idle	.	.	.	.	.	31·87

Time idle is due to the following causes :

						Per cent.
Lack of water	.	.	.	.	.	6·63
Lack of pressure	.	.	.	.	.	0·25
Waiting for wagons	.	.	.	.	.	42·70
Falls of rock	.	.	.	.	.	1·44
Drilling	.	.	.	.	.	1·37
Mud-bound	.	.	.	.	.	8·38
Preparing ground	.	.	.	.	.	10·75
Derailments	.	.	.	.	.	4·00
Damage to machinery	.	.	.	.	.	19·16
Various	.	.	.	.	.	4·67

Mine Transport.—The Bilbao district has a great variety of haulage systems, already enumerated and detailed by Gill, some of them like the Orconera main incline plane, still a model of its kind. These systems have undergone few changes since 1896 other than in details, and in the almost general trend towards the substitution of electricity for steam.

The F. B. Concha 2 mine will be visited by some of the members and is not described in Gill's paper. The Concha 2 mine is the chief source of that company's spathic ore ; it is worked in part by opencast and partly underground. In the following description reference will be made to the accompanying sketch plan of the mine (Fig. 2, *A* and *B*), in which the levels of the more important points are noted.

The mine is divided into five principal levels, each one being some 25 m. high, joined up by means of chainways which deliver the products into a central installation where two lines of aerial ropeways commence, one line for the ore, one for the rubbish. The chainway tubs, of 50-cm. gauge, are about 60 cm. high, with a capacity of 1000 kg. of ore. The links of the chain measure 15 and 26 mm., and the weight of the largest chain is 16 kg. per m. The capacity of the ropeway buckets is the same as that of the tubs ; it thus being possible to transfer direct from wagon to bucket.

The installation is excellently arranged, advantage being taken of the change in direction for coupling up the chains on different levels. The speed is regulated by means of brakes and revolving balanced wheels, which generally turn in water in order to avoid increasing the size of the blades. The capacity of the installation depends on that of the ropeway, which is limited to 370 tons per hr.

The central transfer station, where the products are transferred from the tubs to the ropeway buckets, consists of several revolving tippers arranged in series on a closed-circuit railway line, with the gradient in favour of the load. Tipping takes about 40 seconds.

Arguments in favour of the chainway system are : Greater facility for hand-loading, because of the lower height of the tubs, which gives the loader a 15 per cent. greater efficiency. Better adaptability to the irregularities of the ground, smaller curves, less excavation for lines, and a high yield per man on transport, when the installation is working to its full capacity.

Arguments against that system are : The necessity of breaking
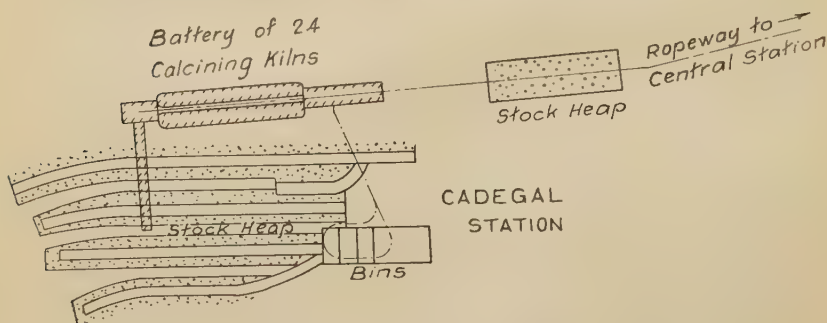
FIG. 2A.—Plan of Concha 2 Mine.   (See Fig. 2B.)
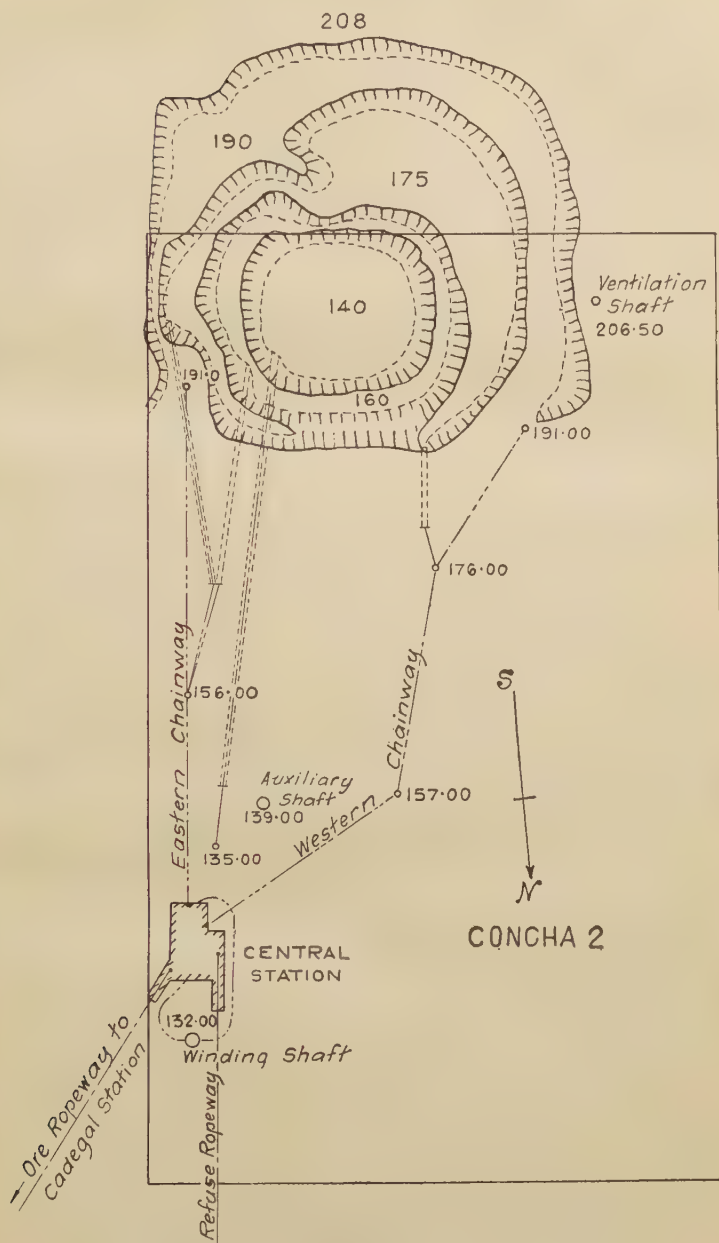
FIG. 2B.—Plan of Concha 2 Mine.   (See Fig. 2A.)

rocks small so as fully to utilise the tubs, difficulties for combining with mechanical loading, higher first cost, and difficulties in cutting down the number of men on transport work when the production diminishes.

The underground portion of the mine will be served by a main shaft equipped with two cages, and placed adjoining the central transfer installation.   The underground tubs will be the same as those used on the surface chainway and will pass on to the same transfer installation.

Besides the main shaft there is a shaft at the higher part of the mine, and an auxiliary shaft at the level 365.

The principal data of the main shaft are :

Diameter of shaft	7 m.
Depth	70 to 250 m.
Net load	2000 kg.
Weight of cage	2000 ,,
Weight of tubs	2000 ,,
Diameter of cable	33 mm.
Weight of cable	3·73 kg. per m.
Diameter of drums	3·200 m.
Width of drums	2·600 m.
Motor	170 to 270 H.P.
Motor, r.p.m.	275
Drum, r.p.m.	22

The motor is a three-phase machine operating at 220 v.   One of the drums is adjustable in relation with the other.   The usual safety devices are provided.   The head-frame is 31 m. high, the pulleys are 3·5 m. in diameter.   The total weight of the headgear with accessories is 130 tons.   The ventilation shaft is 3·80 m. in diameter and 116 m. deep.   The auxiliary shaft is 65 m. deep and 4·80 m. in diameter.   The normal capacity of the installation is estimated at 1500 tons per day.   At present the ventilation shaft is completed, and the main shaft has been sunk to a depth of 157 m.   The head-frame and one of its two winders are also finished.   The main galleries have also been cut through, and only a few details remain to be completed before commencing extraction.

The system of exploitation is not yet fully decided upon ; to begin with, it is to be the room-and-pillar method followed by filling.

Aerial Ropeways.—Aerial ropeways are particularly well adapted to the hilly nature of the Vizcaya district and to the numerous obstacles in the way of establishing railway lines.   The

original Hodgson ropeway described by Gill is still to be seen, though reduced to-day to two lines of buckets.

There are, besides, a series of mono-cable ropeways in different mines. The most important ropeways in the district are those of Orconera, Franco-Belga, and that recently erected by Parcocha. These three are all twin-cable ropeways on the Bleichert system.

Orconera Ropeway.—This carries ore clays from the mine station at Carmen 7 to the washery by the sea at Poveña. The washed ore passes through a bunker, and is carried by the return buckets as far as Pucheta. The buckets here empty into another bunker, and continue their journey empty back to the mines. From Pucheta a branch ropeway carries the washed ore to a third bunker at the company's railway terminus at Gallarta. The branch carrying clays from the mines to Poveña is a double-return installation, that from Pucheta to Gallarta a single-return installation. The characteristics of the Bleichert system are too well known to need description here. Profiles of the end sections of the Carmen 7–Poveña ropeway and of the Pucheta–Gallarta ropeway are shown in Figs. 3 and 4 (Plates I. and II.).

The principle data are as follows :

Distances.						M.
Carmen to Poveña	.	.	.	.	.	8066
Carmen to Pucheta	.	.	.	.	.	3710
Pucheta to Gallarta	.	.	.	.	.	1800

Levels.			M.
Height of Poveña above sea-level .	.	.	90·20
Difference in level between :			
Carmen and Poveña	.	.	.	242
Pucheta and Gallarta	.	.	.	128

Speed, 2·5 m. per second.

Space between buckets, 64 m.

Capacity.					Tons per hr.
Main lines ; clays	.	.	.	.	220
Main lines ; washed ore	.	.	.	96 to 120
Branch (Poveña to Pucheta) .	.	.	82 ,, 100

Cables.		Diam. Mm.	
Carmen to Poveña,	2 carrying ropes .	43 (locked coil)	
Poveña to Pucheta,	2　　,,　　　,,　.	45	,,
Pucheta to Carmen,	2　　,,　　　,,　.	26	,,
Pucheta to Gallarta,	1 carrying rope .	43	,,
Pucheta to Gallarta,	1　　,,　　　,,　.	26	,,
Carmen to Poveña,	2 tractor ropes .	26	
Pucheta to Gallarta,	1 tractor rope .	20	

Loads.

			Kg.
Load per bucket ; clays	.	.	740 to 750
Load per bucket ; washed ore	.	.	800 ,, 1000
Load on branch	.	.	610 ,, 750

Counterweights of carrying ropes.

				Kg.
45-mm. ropes	.	.	.	26,600
43-mm. ,,	.	.	.	24,200
26-mm. ,,	.	.	.	9,400
26-mm. tractor	.	.	.	9,500
20-mm. ,,	.	.	.	9,500

Power.

Carmen 7 station : two 100-H.P., 3000-v. motors.
Gallarta station : one 100-H.P., 3000-v. motor.

Only one of the two motors of the Carmen station is working normally, consuming 14 to 16 amp. The Gallarta motor absorbs 20 amp.

Bunkers.

			Tons.	
Poveña ; clays	.	.	3000	
Carmen 7 ; clays	.	.	600	(loading station)
Poveña ; washed ore	.	.	1500	
Pucheta ; ,, ,,	.	.	2000	(to the branch)
Gallarta ; ,, ,,	.	.	5500	(terminus bunker)

The complement of men on this ropeway totals 90, of which 9 men are employed inspecting the line and on light repairs. The maximum distance between trestles is 200 m. ; the tallest trestle is 28·5 m. high.

Franco-Belga Ropeways.—The Franco-Belga ropeways are, like those of the Orconera Co., on the Bleichert system, the carrier being suspended on two wheels.

The principal characteristics are :

Bucket capacity .	.	.	.	.	1000 kg.
Speed of cable .	.	.	.	.	2 m. per sec.
Rubbish ropeway	.	.	.	.	200 tons per hr.
Ore ropeway .	.	.	.	.	175 tons per hr.
Diameter of rope carrying full buckets	.				52 mm.
Diameter of rope carrying empty buckets					22 mm.
Diameter of tractor cable	.	.	.		22 mm.

Parcocha Ropeway.—This is the most modern installation in the district. It transports ore from Parcocha Mine to the station of Arcocha on the Triano Railway (see Fig. 5, Plate III.). This installation, also on the Bleichert system, has carriers suspended on four wheels so as to diminish the flexion of the cable. The ropeway has a total capacity of 700 tons per day, a net load per bucket of 850 kg., and a speed of 2·25 m. per second. The com-

plement of men is 21, including the loaders and unloaders at the stations. The general arrangement of the stockyard is efficient, and allows the buckets to be unloaded at any point in the dump. The cost of reloading from this stockyard into railway wagons is 8 to 10 centimos per ton (under 1 penny).

Ore Washing.— The problem of washing the " chirtas " of Vizcaya, as also those of the adjoining province of Santander, is at present almost reduced to the separation of the clay from the ore by using large quantities of water in a trommel or beater. When the clay has been washed away by the water the ore is spread out on belts or turntables. The installation owned by the Orconera Company in Poveña is representative of the system of washing plants in Vizcaya.

The Orconera Company has such a large quantity of clayey ore that it was impossible to find sufficient quantities of water for treating it at the mines. The company decided, after considering the possibility of bringing sea-water and sending the slimes to the sea, to erect the ropeway described, in order to carry the clays to the sea at Poveña, where the washing would be done.

The installation has a capacity of 180,000 tons per annum (washed ore) for clays containing about 40 per cent. of ore (see Fig. 6). The ropeway buckets on arrival are discharged on to a dump, whence, by means of six hose-pipes, the clays are washed into the trommels. There are 6 large trommels in groups of 2 ; they are formed of 4 rings, each $2 \cdot 21$ m. in diameter and $1 \cdot 25$ m. long, and a truncated cone with an opening 600 mm. in diameter. The axes are exactly horizontal. In the cylindrical part there are 10 beaters with steel-plate spirals between them. In the truncated conical part is a perforated spiral which forces out the washed ore. The number of revolutions per minute is 7 to 8. These trommels are driven by a 165-H.P. motor, which transmits power to three shafts placed above each group of trommels by means of a rope drive. The rotary motion of the shaft is transmitted by belts and gear-wheels to a toothed ring surrounding the trommel, which is also encircled by two steel rings, each running on two rollers. Each trommel discharges its ore by means of the spiral in its cone on to belts 3 ft. wide and 8 m. long, travelling at a speed of 48 ft. per minute. Eight boys are employed on each belt. The water and clay inlet is placed on the cylindrical side of the trommel.

After washing the clay, the water containing the fines flows out
again through the cylindrical end at the back.

The fines, dumped into two small pits, are raised by two
dredgers with perforated buckets, and passing through two small
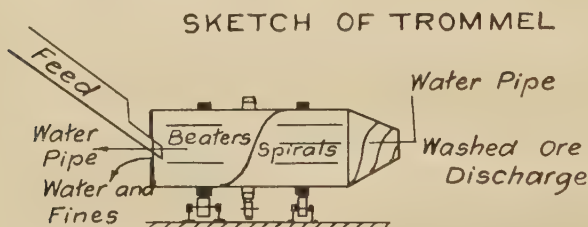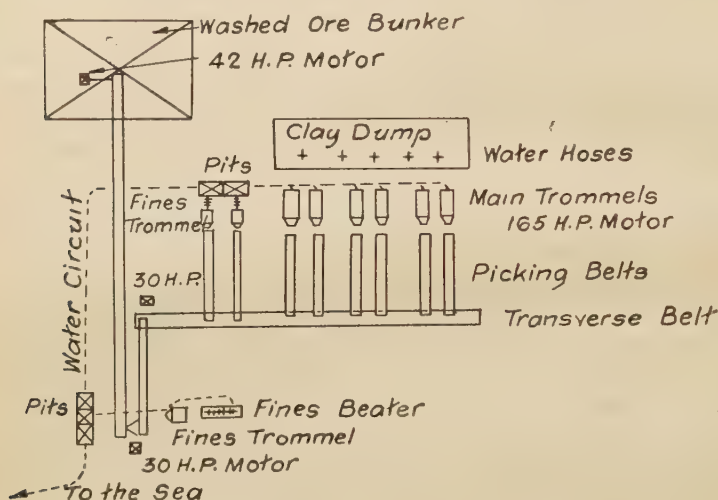
FIG. 6.—Flow Sheet of a " Chirta " Washery.

trommels are discharged on to two cross-belts 18 in. wide.   These
two belts, together with the six on which the picking is done, feed
a cross-belt 2 ft. wide, and by means of another series of belts the
washed ore is raised to the 2000-ton aerial ropeway bunker.   To
recover the fines carried by the water after passing the two pits,
there are other settling boxes, which feed a small trommel through
a beater, and finally discharge on to a washed ore belt.   The
installation requires a 165-H.P. motor to drive the trommels, two

30-H.P. motors for the conveyers, and one of 42 H.P. for the elevating conveyor to the bunker. The water from the washery, with the slimes in suspension, goes into the sea.

The pumping installation is composed of two 260-H.P. pumps which raise the water from the sea to a height of 90 m. One of the pumps is kept in reserve. The large motors operate on 3000 v. ; the remainder work on 220 v.

The labour employed is generally as follows :

> 8 men discharging buckets.
> 6 men at the hose-pipes.
> 6 men feeding into the trommels.
> 48 boys classifying ore.
> 2 men on the fines trommels.
> 1 man on the last fines trommels.
> 4 foremen.
> 2 greasers.

The output from the picking belt is some 450 kg. per man, varying to some 700 kg., according to the size of the ore. The fines (ore smaller than 5 mm.) usually constitute 4 per cent. of the total. The analysis of the lumpy ore on the dry weight gives 55 per cent. of iron, and the fines 46 per cent. The fines, besides having a smaller iron content, are also higher in phosphorus.

Nearly all the washeries in the district have the same type of plant as that described. Recently, washeries have been erected where the fines pass through jigs, and good results have been obtained. These jigs, installed in the mines Elvira, Berango, El Morro, and San Luis, are the result of the work of the mining engineer, Don Jesus Arana.

The problem of washing the fines is not new in the district. Washeries with jigs have on several occasions been tried, but without result. This class of washery, for separating the ore from the gangue which differs very slightly in density, requires that the apparatus should give a high output with a small water consumption, and failure in several cases has resulted from this cause. In the jigs in use to-day, the ore is discharged through a sieve, which has variable holes increasing in size ; the waste is carried away by the water. The strong suction of these jigs favours the separation of ores that have not been classified according to volume.

The results obtained are as follows :

The unwashed ore contains 42 per cent. of iron and 27 per cent.

of silica, and the concentrated ore contains $6 \cdot 5$ to 7 units of iron more.   The silica is reduced by 10 per cent., losing 25 per cent. in weight.   All ore smaller than 15 mm. is sent to the jigs, and each jig washes daily 30 tons of crude ore.

The average cost of ore washing is given in Fig. 18 (p. 48).

Calcining Spathic Ore.—In the early times the fines of the spathic ore were separated, and the first attempt in the district to calcine spathic ore was made by the Franco-Belga Company. This was successful, and then several kilns were constructed in the district.   All these kilns have been of the stack type.   It was also the Franco-Belga Company that introduced the use of forced draught, which was later adopted by several other companies. Most of the kilns are cylindrical, with four doors for the discharge of the calcined ore, but the Franco-Belga Company has now adopted a type of kiln elliptical in shape and lower than the generality.

In describing the installations of the Orconera Iron Ore Company and Franco-Belga Company, the author will endeavour to give a fair idea of the present status of the problem.   In general, the production of the kilns per shift has been about $0 \cdot 6$ to $0 \cdot 7$ ton of calcined ore per cu. m. of capacity.   At the present time the problem of increasing the production per kiln has taken another turn, the present General Manager of the Orconera Company, seconded by his mechanical staff, being the pioneer of this task. The results have been brilliant, and the production has increased to $1 \cdot 2$ to $1 \cdot 5$ tons per cu. m. of capacity per shift.

Orconera Iron Ore Company, Ltd.—This company has 12 kilns grouped in batteries of four.   All are situated near the main railway.   The batteries of kilns 1 to 4 and 9 to 12 are in line and at the same level as the railway.   The $7 \cdot 5$-ton hopper-bottom railway wagons of spathic ore are raised by a double-acting electrically operated incline, and are run directly over the tops of the kilns.   The direction of this incline is at right angles to the line of kilns, and is placed at the middle of the battery.   The wagons are moved from the head of the incline to and from the kiln, where they are discharged by an endless rope which passes through two grips on the tractor.   The capacity of each of these kilns is about 100 cu. m.   The height is $12 \cdot 50$ m. from the base to the top, and the cones are about 2 m. high.   The diameters are

PLATE I.

LOADING STATION
CARMEN 7ª

CAMPOMAR
STATION
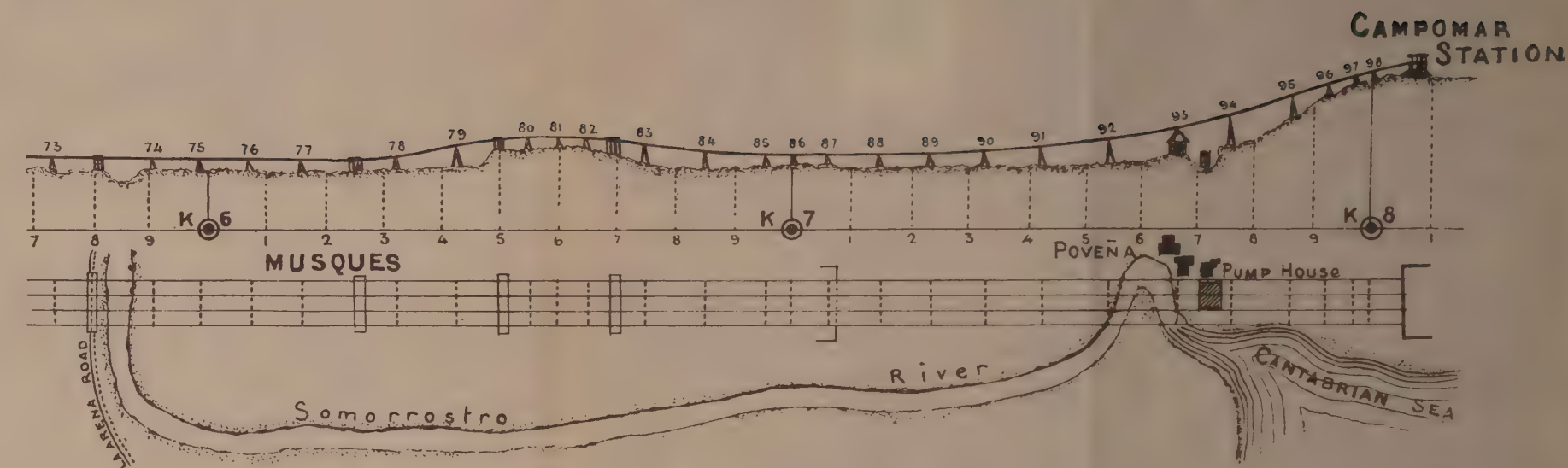
FIG. 3.—Orconera Aerial Ropeway; main line.

PLATE II.
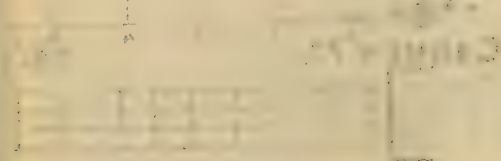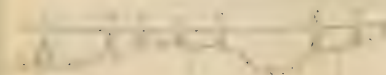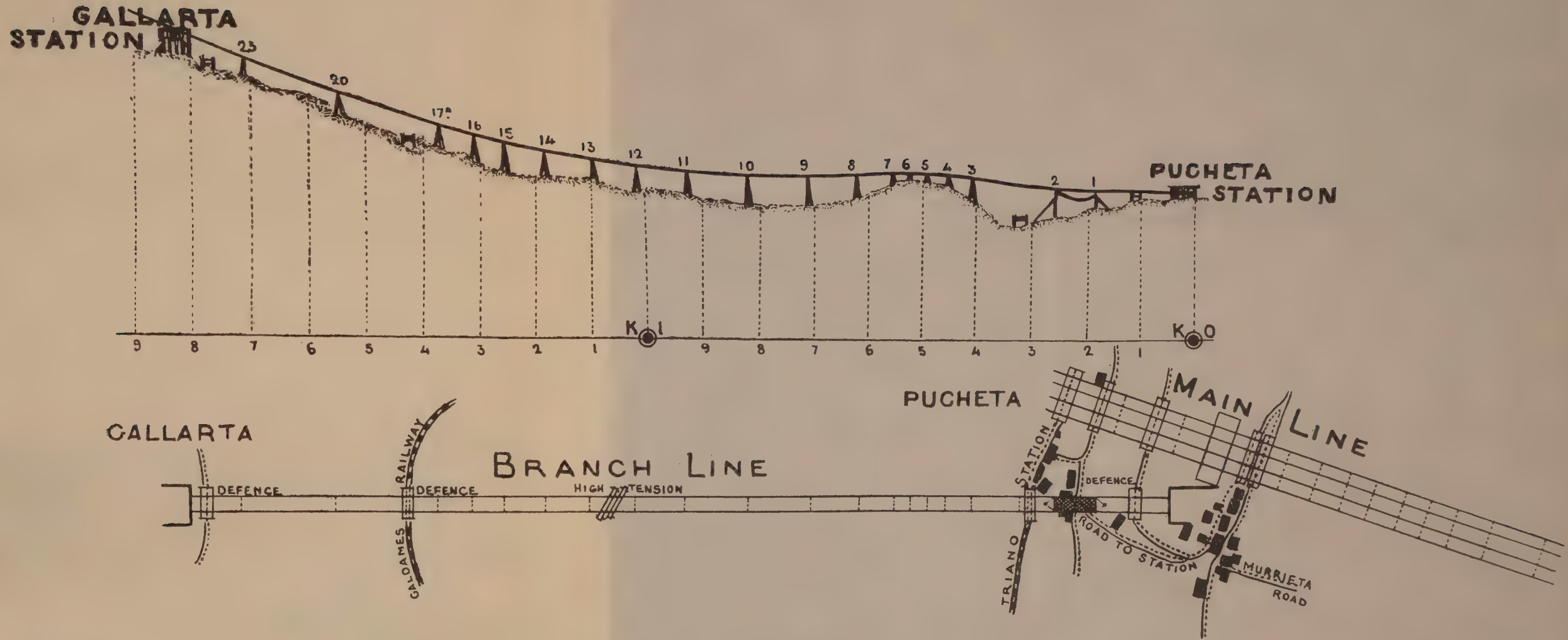
FIG. 4.—Orconera Aerial Ropeway ; branch line.

PLATE III.

LOADING STATION

Equinoxial sea level
GROUND LEVEL
DISTANCE BETWEEN TRESTLES
HEIGHT OF TRESTLES
LENGTH OF CABLE K.50.

LOADING STATION

DISCHARGING STATION

TRIANO RAILWAY

LAS DELICIAS

K.⊙2.

FIG. 5.—Parcocha Aerial Ropeway.

LOADING STATION

LOADING STATION

PLATE IV.

SECTION A-B.
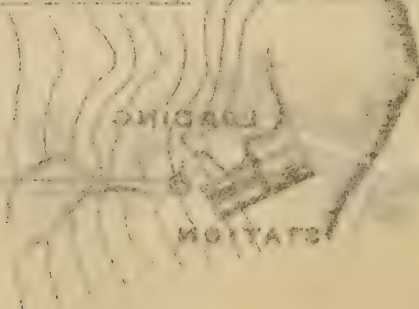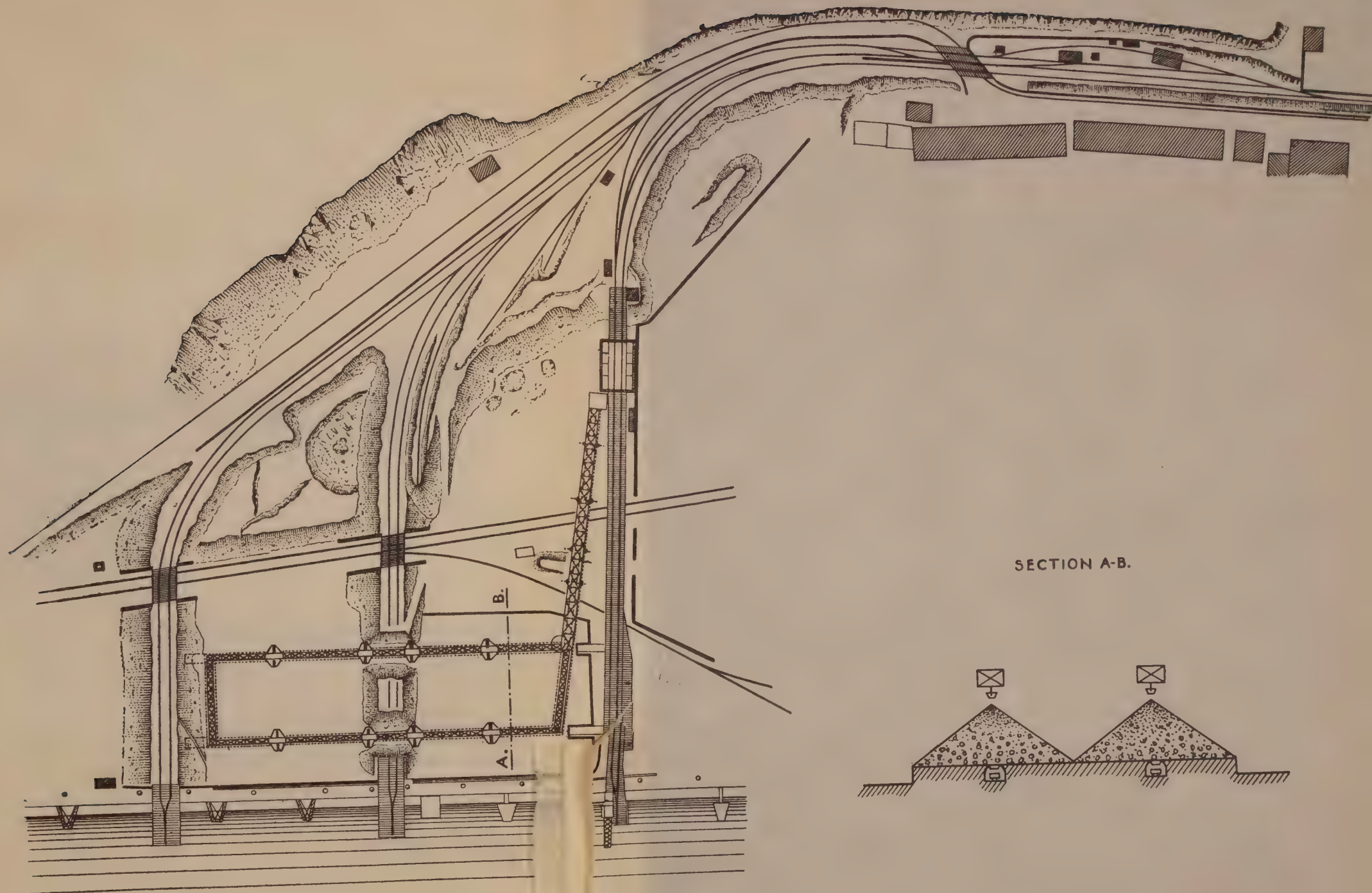
NERVION RIVER

Fig. 9.—Termi ation, Dump, and Loading Staith of the Franco-Belga Co.

PLATE V.
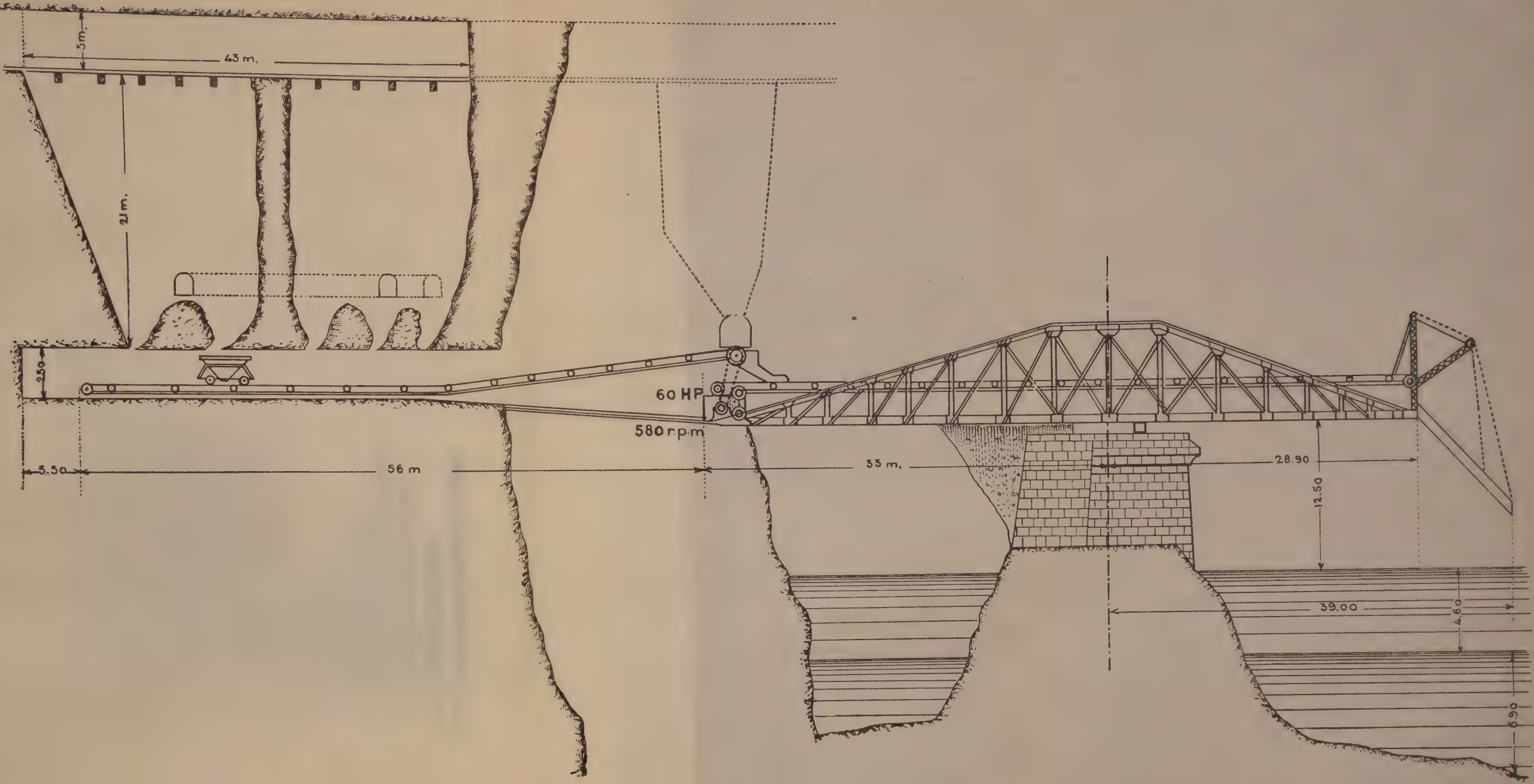
FIG. 10.—Setares Shipping Staith.

PLATE VI.
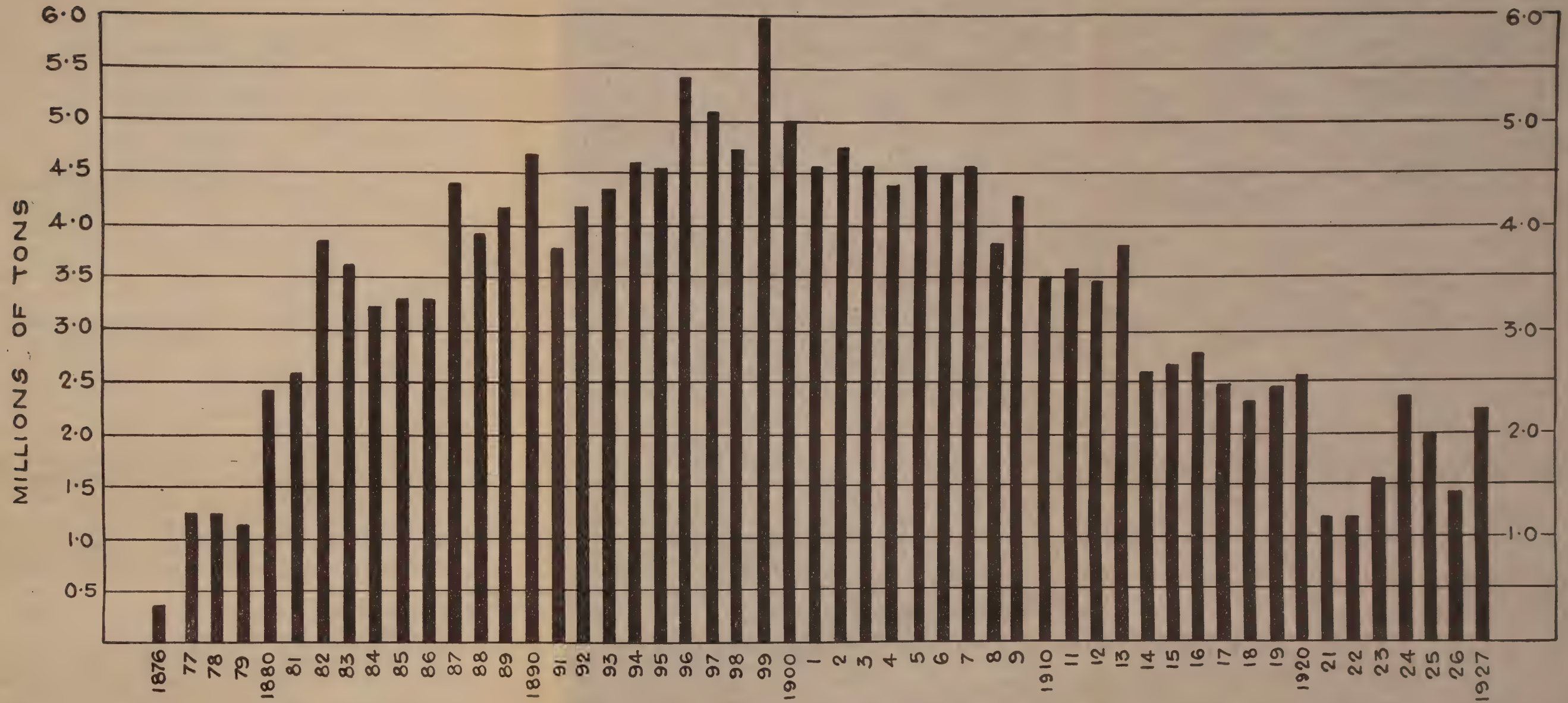
FIG. 11.—Yearly Production of Vizcaya Mines.
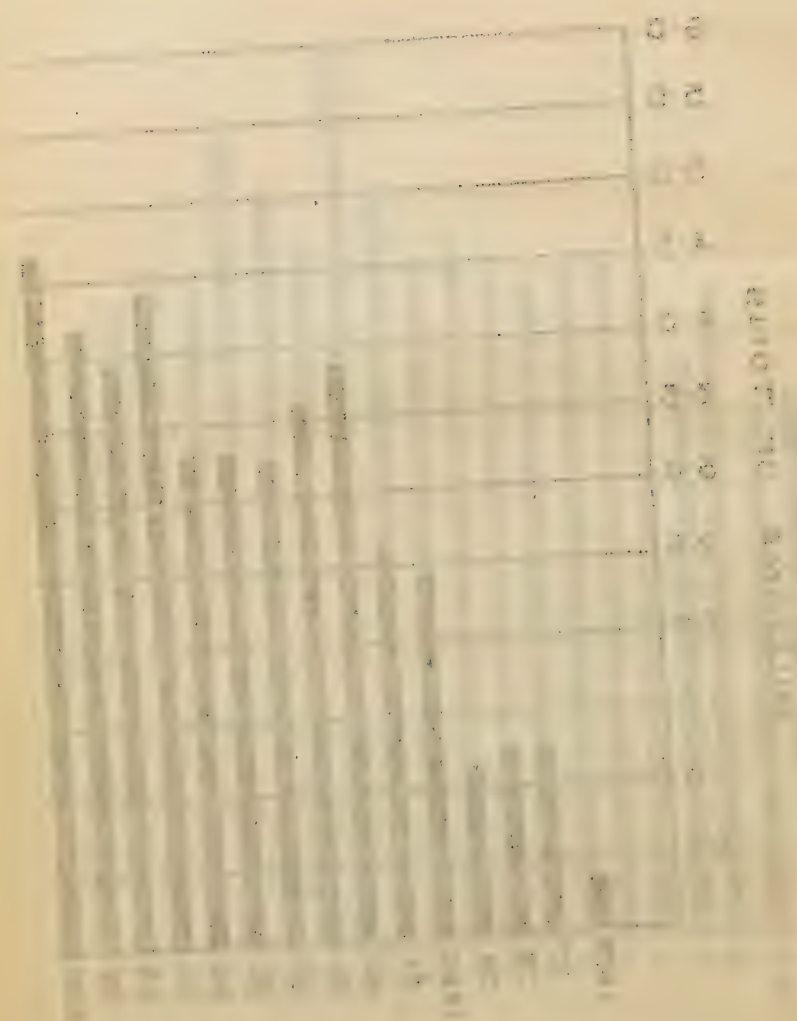
4·10 m. and the kilns are cylindrical in form. The insides of the kilns are of firebrick, and the outsides are common brick bound with iron bands at intervals.

The discharge is effected through openings placed symmetrically, which are shut by means of iron doors ; screws make the joint between the door and the kiln air-tight.

The air is distributed from the centre of the cone, and also through points in the doorways. The cones, which are made of steel plates, are very steep, to facilitate the discharge of the calcined ore. One-fourth of the calcined ore is held in the kilns by means of two gates in each opening. These gates are pivoted and in their natural positions are shut. When it is desired to discharge a kiln the gates are raised from the outside by means of shafts passing into the kilns, whose inner ends have chains joining them to the gates. These chains wind round the shafts, thus raising the gates. The calcined ore flows easily without the necessity for any scraping, except when large masses of fused ore block the gates (called locally *bolas*).

Round each kiln there is a revolving tray which collects the calcined ore and conveys it to a fixed discharge point. In the battery of kilns 9 to 12, these trays discharge into the buckets of an aerial bucketway. These buckets in turn are discharged from a travelling bridge over the dump. In the battery of kilns 1 to 4 the ore is discharged from the tray through a chute on to a stockheap, where an overhead travelling crane, equipped with a 2-ton Priestman grab, takes the ore and deposits it at any desired point on the heap. At the battery of kilns 5 to 8, the ore is drawn into wheelbarrows and wheeled on gantry platforms to the stockheap.

The stockheap of battery 9 to 12 has a useful surface of 2400 sq. m. and a height of 3 m., the capacity being about 8000 tons. Battery 1 to 4 has a stockheap 25 m. wide, 50 m. long, and 6 m. high, thus giving a capacity of about 10,000 tons. Before the modifications were made, half the ten-hours' working day was employed in drawing the kilns, and during the other half they were under blast. Since the modifications each drawing takes 8 to 10 minutes, *i.e.* about 40 minutes per day, the rest of the time being available for blowing.

At the present time, as the modifications are still in progress,
1928—ii.   D

it is impossible to state exactly the number of men necessary for each battery, or the period of most economical blowing.   The
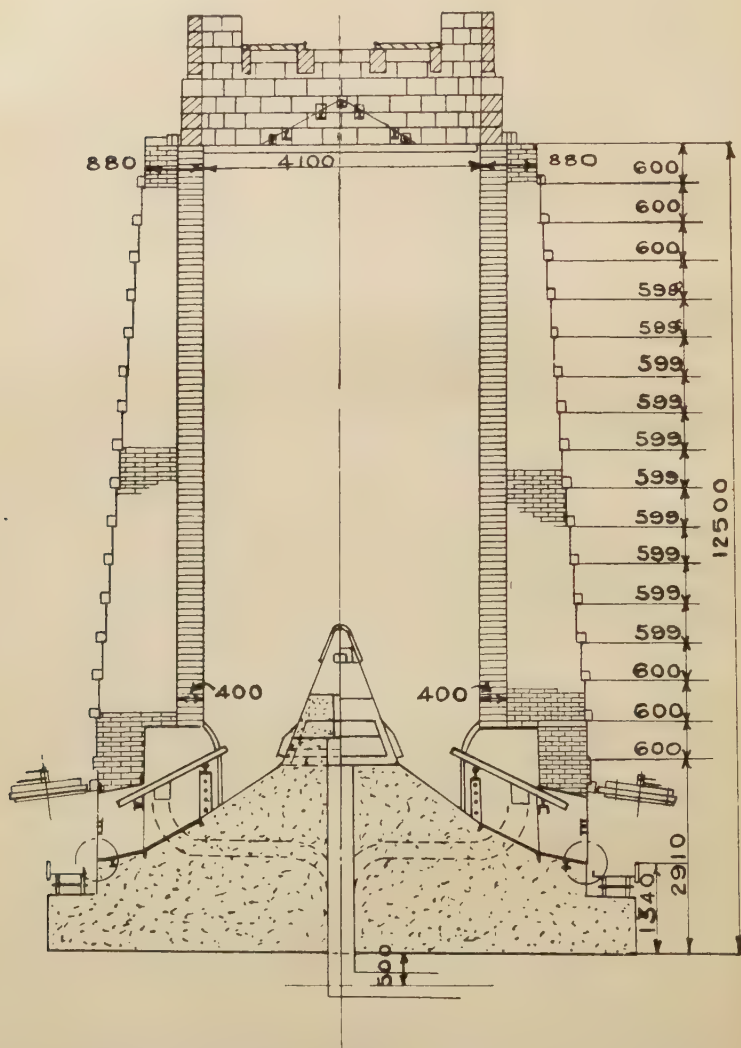
Fɪɢ. 7*A*.—Sectional Elevation of a Calcining Kiln, Orconera Co.   (See Fig. 7*B*.)

production before was 60 to 70 tons of calcined ore per kiln per day, and to-day it has risen to 125 to 150 tons per day, *i.e.* 1·25 to

1·50 tons per cu. m. In view of the increased output and the consequent difficulty of obtaining ore sufficiently cool to ship, water-spraying has been adopted with considerable success. The maximum temperature of ore for shipment is 80° F. The coal consumption is about 2·25 per cent. of the calcined ore. The coal used contains 27 per cent. of volatile matter.
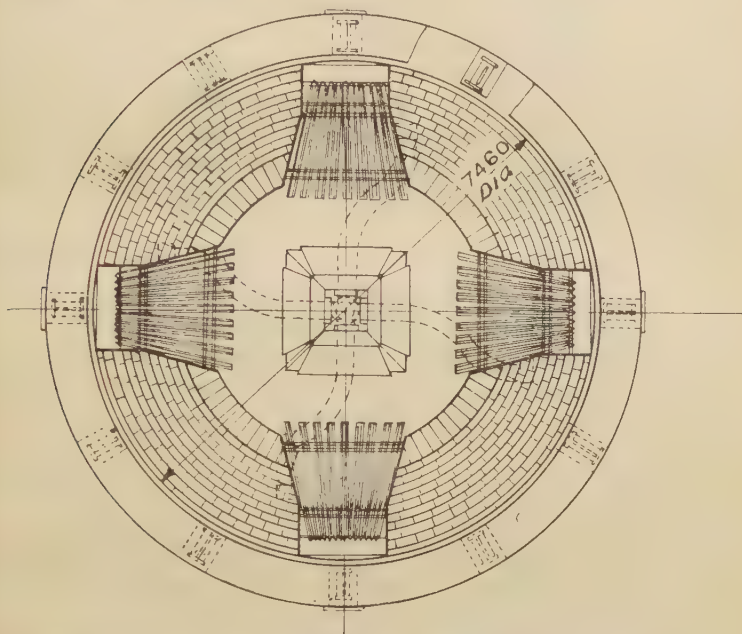
FIG. 7B.—Plan of Hearth Section of a Calcining Kiln, Orconera Co.
(See Fig. 7A.)

Fig. 7, A and B, show a sectional elevation of a kiln and a plan of the hearth. Plates VIII. and IX. show photographs of the installation.

Every pair of kilns has one fan driven by a 62-H.P. electric motor. The pressure is about 25 cm. of water. These motors also drive the tray and the aerial bucketway. The inclined plane for the crude ore is driven by a 55-H.P. motor. The travelling grab has a 40-H.P. motor for elevating, one 10-H.P. motor for the travelling bridge, and a 5-H.P. motor for the travelling car.

Franco-Belga Company.—This company has adopted a lower type of kiln. It is of elliptical section, formed by two semicircles

of 1·5 m. radius joined by a straight portion 0·56 m. long.   Its
effective height is 5·85 m.   The kilns are built in sets of two.   It
is proposed to build 24 kilns arranged in two parallel lines of six
sets each, but at present only four kilns of the second line have
been constructed.   These four kilns are 60 cm. higher than the
others.

The discharge of the kilns is made through two doors placed
symmetrically on the short axis.   The width of each door is 50 cm.
Calcined ore is discharged into a bin of about 10 tons capacity
below each set.   These bins are discharged through the bottom
by means of a mechanical feeder on to an apron conveyor which
runs under each line of kilns.   Both conveyors discharge into
a transverse conveyor which carries the calcined ore to the main-
line wagons.

The calcined ore is cooled in the general stockyard owned by
the company at Requeta, the terminus of its general railway.
When it is not desired to load direct into wagons the conveyor
can discharge into hopper-bottom tubs which are run over a local
stockheap.   The crude ore arrives by a cableway, and the buckets
pass over the tops of the kilns or can be discharged on to a
stockheap.

The blower has a pressure of 12 cm. of water.   Each fan blows
four batteries, and the blast enters from the bottom and passes
through the furnace grate which forms the base.   The sectional
elevation of the company's kiln (Fig. 8) shows both the old and
new position of the bottom.

As a result of the modification recently adopted by this
company, the production has reached 60 tons as compared with
43 tons.

The fuel employed is coke breeze, and the quantity used is
26 kg. per ton of crude ore.   The kilns work only one 8-hours'
shift, and at each kiln one man is employed for drawing.   Only
four hours' blowing is done at each kiln, the amount of air being
2 cu. m. per second.

In this manner the production per man/shift is 20 tons.   The
coal consumption is 36 kg. per ton calcined, and the cost for
blowing and conveyors about 10 centimos (under 1 penny)
(the cost of energy being 14 centimos per kw.-hr.).

A comparison of this type of kiln with those generally in use

in the district shows the advantages of the better handling of materials : less formation of dust in the process of calcination ;
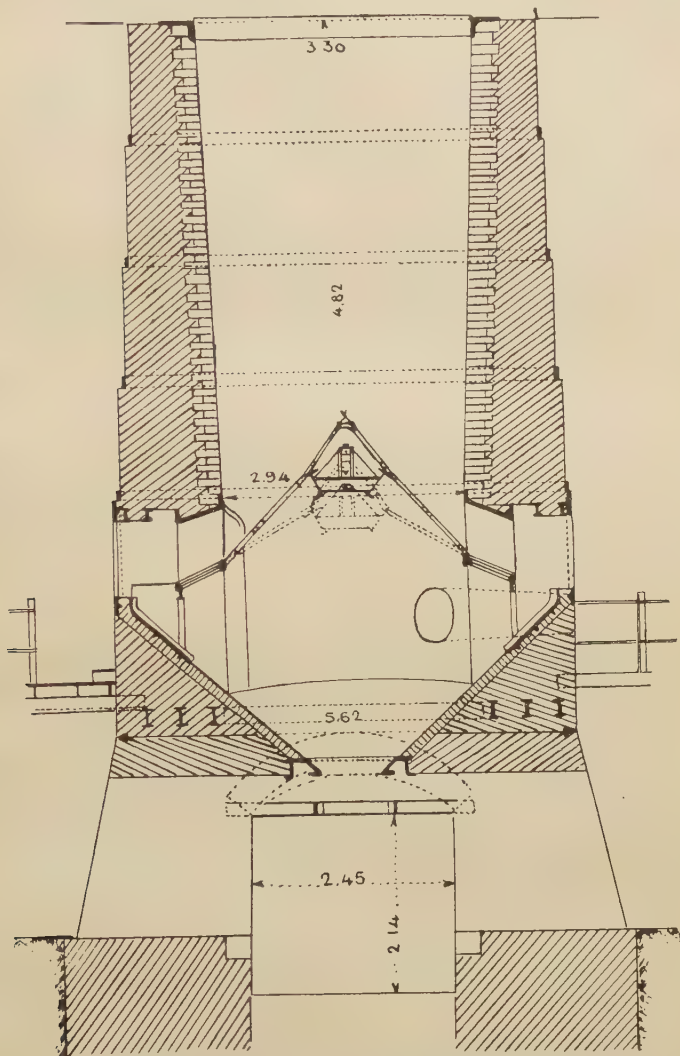
Fig. 8.—Sectional Elevation of a Calcining Kiln, Franco-Belga Co.

less difficulty in breaking up the *bolas*. Against these must be set the following disadvantages : less regularity in the drawing

due to the number of doors; an increment in the capital cost, due to greater quantity of materials employed per ton produced ; and the difficulty of reducing labour, due also to the fact that with two doors it is very difficult to draw all the calcined ore by gravity.

Looking at the results of present-day kilns and of the former type, it can be said that the increase in output is due to two principal factors, (1) mechanical and (2) chemical.

With the stack type of kiln, as described, the current of air tends to go to the sides rather than to the centre ; thus the line of equal temperature is lower at the centre than at the walls.

If the cone is sharper and there is a current of air at the apex, the fire zone tends to form a flatter surface, thus increasing the useful draught of the kiln.

In the calcination of carbonates of iron the reaction of decarbonisation appears to proceed similarly to that of other metallic carbonates, followed by a peroxidation of the oxide formed.   The first appears to be a reversible reaction, though this has not been very clearly demonstrated.   The second only takes place in the direction indicated :

$$2FeCO_3 \rightleftarrows 2FeO + 2CO_2 - 32 \cdot 2 \text{ cal.}$$
$$2FeO + O \rightarrow Fe_2O_3 + 65 \cdot 0 \text{ cal.}$$
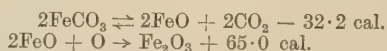
The resulting reaction is therefore :

$$2FeCO_3 + O \rightarrow Fe_2O_3 + 2CO_2 + 32 \cdot 8 \text{ cal.}$$
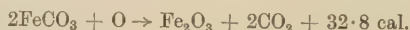
Applying Le Chatelier's law to the decomposition of spathic ore, the process of calcination is favoured, and therefore much more rapid, by diminishing the pressure of the carbon dioxide given off in the course of decarbonisation, and production should thus be capable of increase by the injection of a greater amount of air and by its judicious distribution and application.   The results obtained indicate that by continuing to carry out experiments in a systematic and scientific manner, the cost of calcination will eventually be lowered very considerably.

Underground Mining.—Few mines of the district are worked by underground methods. The two principal ones are the Bilbao and the Onton, in both of which the ore is principally spathic.   In the first-mentioned mine the extraction is made by adits, and in the second by shaft.   In both cases the system

employed is the room-and-pillar method, leaving such pillars as the particular case requires. As a general rule one can put the room at 8 m. and space the pillars at 5 to 10 m., according to the roof pressure and the resisting quality of the ore.

The exploitation of the pillars, if carried out at all, is done by allowing them to cave in on retiring and recovering what one can, or, as was done at Luchana, by mining by systematic " sub-level caving," and trying to recover as much of the timber as possible, even at the expense of mixing the ore with the waste, in view of its high price. In general terms it can be said that there is no system characteristic of the district, the exploitation being generally carried out without pilot workings or much system.

The Dicido Company in the neighbouring province also has underground workings, but these are, so far, rather trial workings, with a larger gallery section than usual in order to compensate for the cost.

As can be seen from Fig. 13 (p. 44), the yield per man underground is just as high as that in opencast, even taking into consideration that the greater part of the ore is spathic.

Railway Transport.—The most important mining railways in the district are :

The so-called Triano Railway, from San Julian de Musques to Desierto ; single line, standard gauge (1·672 m.).

The Orconera Iron Ore Company's railway, from Gallarta to Luchana ; double line, narrow gauge (1·0 m.).

The Franco-Belga Company's railway, from Cadegal (Ortuella) to Requeta (Luchana) ; single line, narrow gauge (1·0 m.).

The Bilbao River and Cantabrian Railway Company's railway, from Galdames to Sestao ; single line, narrow gauge (1·0 m.).

All these are described by Gill in his paper ; it therefore only remains for the author to make a few remarks on their practical results and on modifications adopted.

The Orconera Railway was built on a different plan from those of Franco-Belga and Triano. The latter were laid out along the valley, the ore being lowered to them by means of self-acting inclined planes and ropeways. By this means they arrived at gentle gradients in favour of the load. The Orconera Company,

on the other hand, took its railway direct to the original mines in Gallarta (Cesar, to-day practically exhausted), with a resulting gradient of 22·5 per 1000.   The result is an increasingly expensive traffic with the rise of wages and cost of coal and rolling-stock. The Triano Railway, with its single line, has just as great a capacity as the Orconera double line, and its first cost was infinitely smaller. It is difficult to compare the coal consumption, as that used by Orconera is generally of better quality.

The most important modification made on the railways is the 75,000-ton stockyard built by the Franco-Belga Company at its terminus in Requeta.   The wagons, as they arrive from the mine, can be discharged either directly into the ship or into chutes which feed a line of buckets (Pohlig system) running the length of an elegant steel structure and capable of discharging at any point along it.   One-half of the capacity of the stockheap can be loaded directly on to the loading-belts ; the remaining half has to be stowed by hand or by mechanical loaders.   The aerial cable has a capacity of 200 tons per hr.   The two loading-belts are 1·10 m. wide, with a speed of 0·35 m. per sec., and an average capacity of 300 tons per hr. ; these feed a discharging belt of 600 tons capacity.   The motors used for the belts and cableways are 30 and 25 H.P.   The layout and section of the stockheap is shown in Fig. 9 (Plate IV.).   The maintenance and repair costs of the belts and structures can be taken as 3 centimos per ton (about $\frac{1}{3}$ of a penny).   Also of note, although outside the province of Vizcaya, is the Setares shipping staith with its belt equipment, which allows a loading speed of 800 tons per hr.   The belts are 0·90 m. wide and are driven by a 60-H.P. motor (see Fig. 10, Plate V.).

The Orconera Iron Ore Company has up to the present made no modification other than that of reducing the number of loading staithes to three in order to be able to load larger ships.

The Triano Railway is replacing its end-tipping wagons with hopper-bottom wagons.

The normal transport tariff in the district is 34 centimos per ton-km. (about 3 pence).

Actual Conditions of Iron Ore Mining in the Province of Vizcaya.—According to the Mining Law of Spain, minerals are divided into three categories :

(1) Such minerals as : Stone, clay, limestone, sandstone, granite, basalt, and building material in general ; (2) all the alluvials, bog ores, old dumps, placers, magnesites, phosphates, kaolin, &c. ; (3) metallic ore bodies, coals, oils, precious stones, &c.   The first category belongs to the owner of the land on or beneath which the minerals occur.   The second category belongs to the owner of the land, but the State reserves the right of assigning the concession to an applicant if the owner makes no use of it.

The possession of a concession of the third category is granted to any person applying for the concession of the mining rights, it being unnecessary to consult the owner of the surface, or to prove the existence of mineral.

The minimum unit of surface area for which mining rights can be granted is 4 *pertenencias* (a *pertenencia* is a rectangle of 100 m. square, *i.e.* 1 hectare), and the royalty to be paid, which varies according to the class of mineral to be mined, is 6 pesetas per *pertenencia* for iron ore.

The concession of a mine only becomes void through non-payment of the surface royalty, and the mine itself may be left unexploited as long as the concessionaire desires.   Owing to the insignificance of the royalty paid and to the exploitation of the mine not being enforced within a fixed number of years, many mines containing large quantities of minerals are left unworked. As a general rule the mines are not worked by the owners, but are leased at a certain royalty per ton on a minimum output per annum.   The lessee on his part usually employs a contractor who extracts the ore and puts it into storage.

The royalty paid by the lessee to the owner varies according to the class of mineral.   It oscillates between 0·50 peseta (in very old contracts) and 6 pesetas in some ; the average may be put at about 2 pesetas per ton.

Contracts are usually of two classes.   In big companies like the Orconera, Franco-Belga, and Parcocha to a certain extent, the principal installations, lines, compressors, locomotives, inclines, &c., are the property of the company and are worked under their administration.   The contractor has a contract for one year, placing the output near the main-line railway and into stock, all charges in connection with raising the ore, loading, and

unloading being on his account. In this type of contract a fixed sum is usually paid for each product extracted, be it mineral or overburden.

Usually contracts are given at a fixed price per ton of rubio, spathic, or washed ore placed in stock or loaded into railway wagons. In this case the contractor is liable for all risks. He buys the machinery, and erects inclines, tracks, &c. The price varies from 8 pesetas to 10 pesetas per ton for rubio, and 10 pesetas to 12 pesetas for calcined spathic. The lessee pays all charges for transport and general administration, royalties to the owners, &c.

The mines are distributed to such an extent that the production from each is very small, and much would be gained by general association of neighbouring mines in order to be able to introduce labour-saving devices which for one single mine would not be economical. However, mine owners do not appear inclined to favour general amalgamation, even with their nearest neighbours.

Table II. shows the wages paid for work done in the mines.

TABLE II.—*Average Wages in the Mines*, 1927.

	Wage.	Insurance.	Pension.	Tools.	Total.
	Pesetas.	Peseta.	Peseta.	Pesetas.	Pesetas.
Foremen	9·74	0·39	0·12	...	10·25
Labourers	7·17	0·29	0·12	0·07	7·65
Boys	5·20	0·21	0·12	...	5·53
Drillers	8·125	0·325	0·12	0·10	8·67
Track-layers.	8·065	0·323	0·12	...	8·51
Horse-drivers	7·27	0·29	0·12	...	7·68
Shunters	7·20	0·29	0·12	...	7·61
Sorters	7·20	0·29	0·12	...	7·61
Blacksmiths	9·12	0·36	0·12	And coal 2·20	11·80
Blacksmiths' helpers	7·08	0·28	0·12	...	7·48
Engineers	12·00	0·38	0·12	...	12·50
Trafficmen	9·00	0·36	0·12	...	9·48

For every workman employed in the mines the law enforces the payment of 12 centimos (about 1¼ pence) per day towards the Workmen's Pensions Fund, and the payments for accidents can be taken at about 4 per cent. of the daily wage.

The output per man loading and in the mine—*i.e.* not taking into account transport by locomotives—is shown for different years in cu. m. (loose) in Fig. 12.

In Fig. 13 the production of the different mining companies for the year 1927 is shown, with the total production of all the companies and the corresponding percentage contribution of each to the total output. In the bottom part is shown the total output

Upper curve—Loaders alone.
Lower curve—All men in the mine.
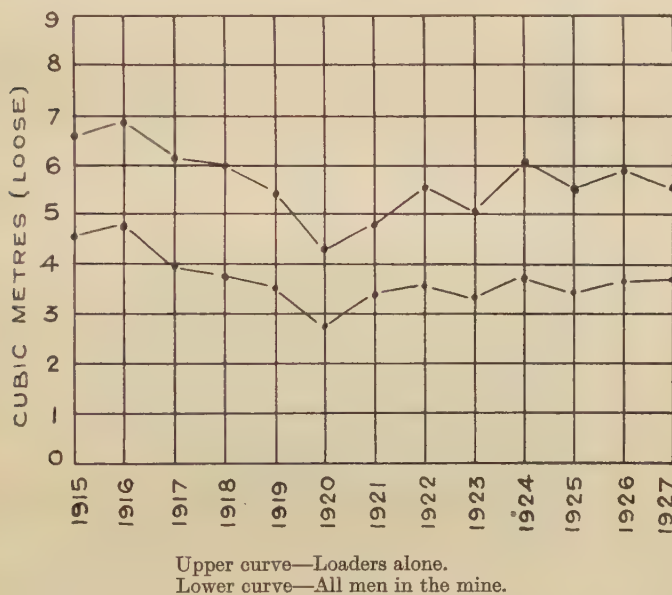
FIG. 12.—Variation of the Output per Man.

per man of clean ore, taken from statistics. This graph is not absolutely exact, as companies possessing railways or ropeways include in their returns personnel employed on this work, and the smaller companies do not, so that these are slightly favoured. From this graph it will be noticed that the Onton and Bilbao mines, which are spathic and underground, show a normal output even better than many opencast mines, in spite of the fact that 20 per cent. is lost in calcination. This is due to the fact that the amount of overburden per ton is generally high in opencast mines, and affects the total production to as great an extent as, or even

greater than, the smaller output of loaders-up in underground workings, and that the spathic mines have less waste than the rubio.

Fig. 11 (Plate VI.) shows the production of the mines in Vizcaya from the year 1876 to 1927. It will be seen that in the year 1899
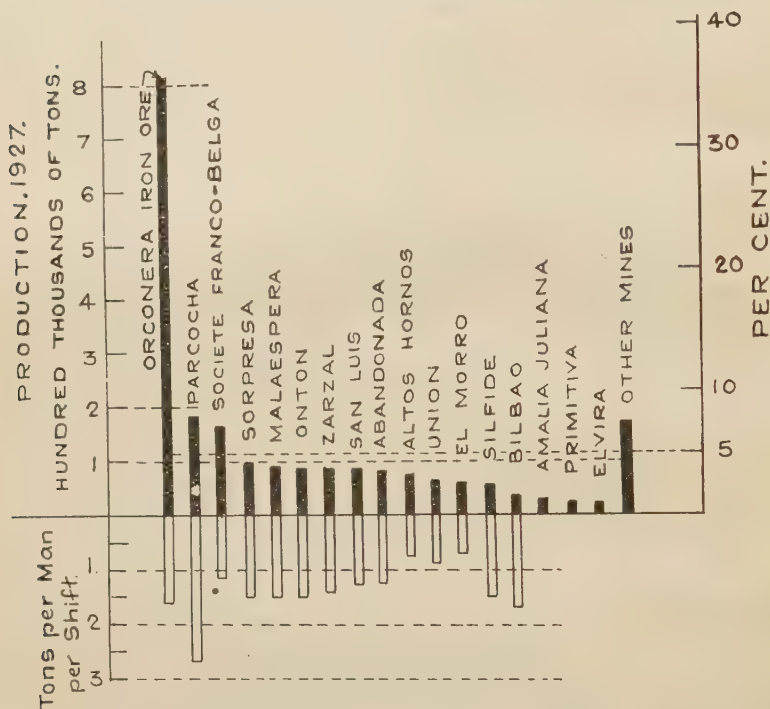
Fig. 13.—The Production of Different Mining Companies for 1927.

the production was the highest, and that in the following years the production has steadily decreased to some 2 million tons.   It will be difficult to increase the production of rubio.   The mines are becoming steadily poorer in this class of ore, and very few have maintained their reserves intact.   Nevertheless, the actual conditions of the mining district will be maintained, or even actually improved, on the basis of spathic.

Fig. 14 shows the cost price of rubio in 1927.   It will be observed that labour costs amount to some 40 per cent. of the

total.   These could be reduced by mechanising methods of loading
and improving transport in big mines.   Owners are to-day tending
to adopt these methods, although many of the mines do not favour
mechanism by reason of their small production.

Transport tariffs are really very high, fluctuating round
34 centimos per ton-km.   Taxes are also very heavy ; this is to
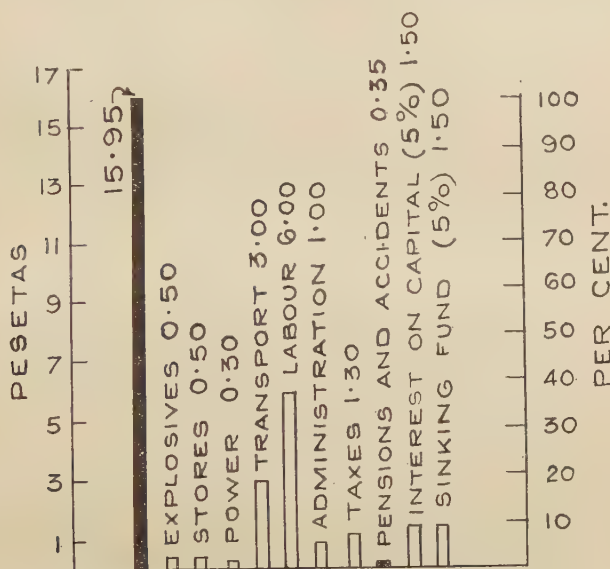
Fig. 14.—Cost Price of Rubio Ore and of Washed
Ore for 1927.

a great extent the result of the prosperous years through which
the industry has passed, when taxes were increased, and now
that it is languishing it is difficult to get them reduced (see
Fig. 15).

In Fig. 16 the cost of spathic ore is shown.   In a general way
the spathic mines can be mechanised under better conditions than
the rubio mines, as the ore is clean, almost free from waste,
and the majority of the mines have considerable quantities of
this ore.

The object of Figs. 17, 18, and 19, is to divide up the previous
graph (Fig. 16), emphasising the most important points—namely,

cost of loading and classification per cu. m. of loose ore and
overburden, and costs of washing and calcination.

The above data give a clear idea of mining conditions in
Vizcaya ; in small isolated mines similar conditions are prevalent
and prices vary according to their situation, amount of over-
burden to be removed per ton, &c.

The sale of ores in Vizcaya is effected according to their
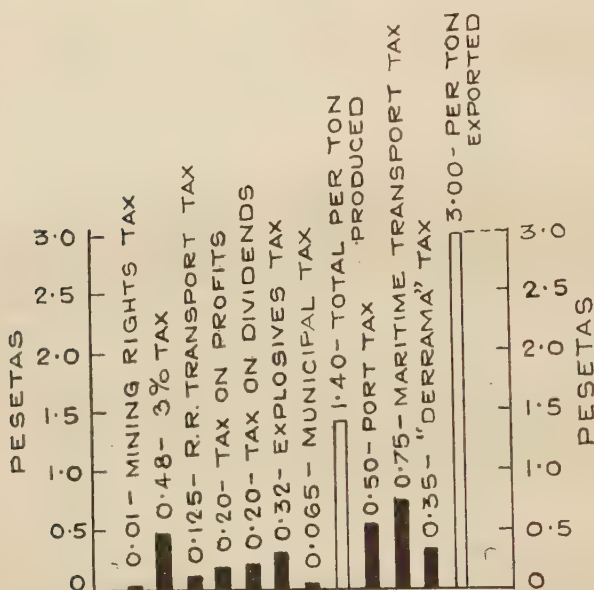
Fig. 15.—Taxes per ton of Ore Mined, and Exported.

quality, known as first- and second-class rubio or spathic. Second-
class ores are sold to a great extent to Germany, and for special
ferro-silicon products, or for mixing with other ores having
calcareous gangues. Prices vary very largely, due to special
circumstances.

The iron content of second-class ores is usually quoted on a basis
of 50 per cent. with a scale of 3d. or 4d. per unit up or down, and
a premium is sometimes paid on the silica content. Best rubio
is quoted on a basis of 50 per cent. of iron as received, with a scale
of 6d. per unit, and 8 per cent. silica with a scale of $1\frac{1}{2}$d. The
phosphorus contents are guaranteed at less than $0 \cdot 020$ per cent.,
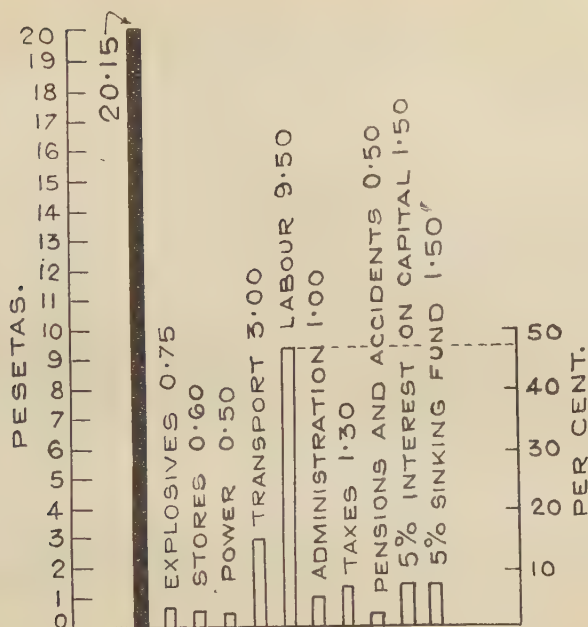
FIG. 16.—Cost of Mining Spathic Ore.
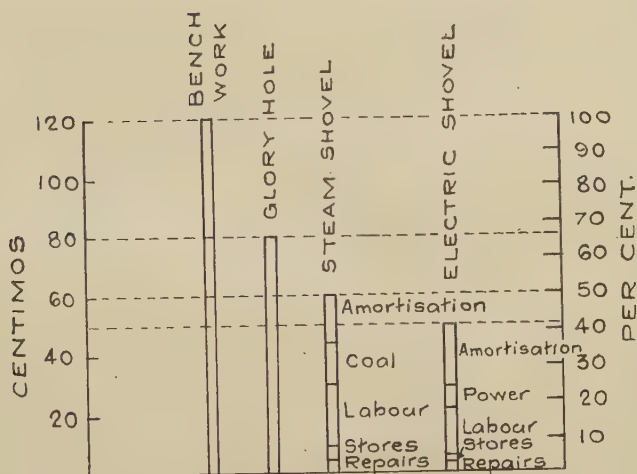
FIG. 17.—Cost of Loading a Cubic Metre of Ore (Loose).
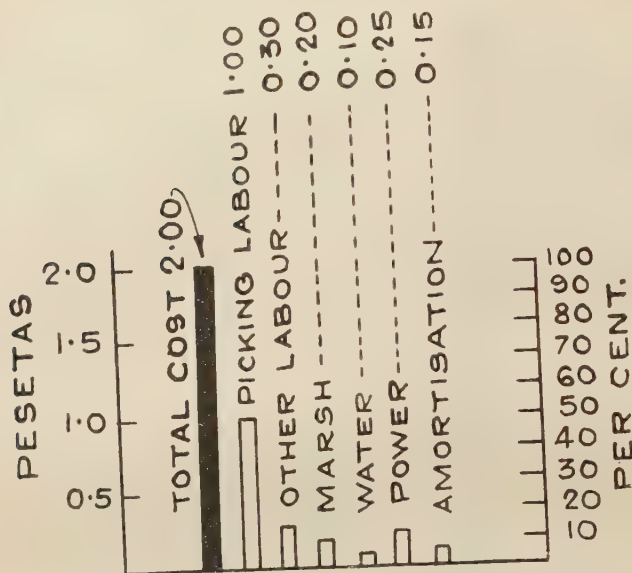
FIG. 18.—Cost of Washing.
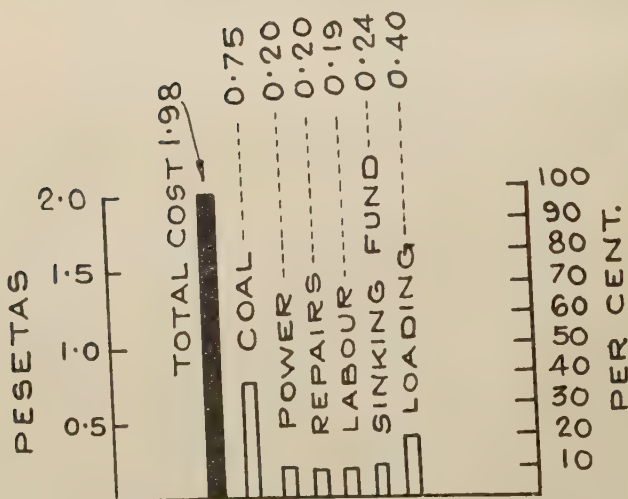
FIG. 19.—Cost of Calcination.

PLATE VII.

A view of the Dicido Mine.

Another view of the Dicido Mine.

PLATE VIII.

Orconera Iron Ore Kilns Nos. 9 to 12.

PLATE IX.

Orconera Iron Ore Dump for Kilns Nos. 1 to 4.

Franco-Belga Installation. Terminus of the mineral railway.

Ruston Steam Shovel Loading Rock. (Note the small size of the wagons.)

Franco-Belga Kilns.

PLATE X.

Orconera Iron Ore Mine. Head of the Main Incline. (See Plate XI.)

PLATE XI.

Orconera Iron Ore Mine.   Head of the Main Incline.   (See Plate X.)

PLATE XII.

Concha 1ᴬ Mine. (See Gill, *Journal of the Iron and Steel Institute*, 1896, No. II. Plate XXIII.)

PLATE XIII.

Concha 1^A Mine.

PLATE XIV.

Concha 2ᴬ Mine.   Opencast.

and if this limit is exceeded the ore is not considered " best rubio "
and the cargo is not accepted.   First-class carbonate is sold on
the same basis as the rubio, no guarantee being required with
regard to phosphorus, as it is taken that no good spathic gives
more than $0 \cdot 015$ per cent. of phosphorus.
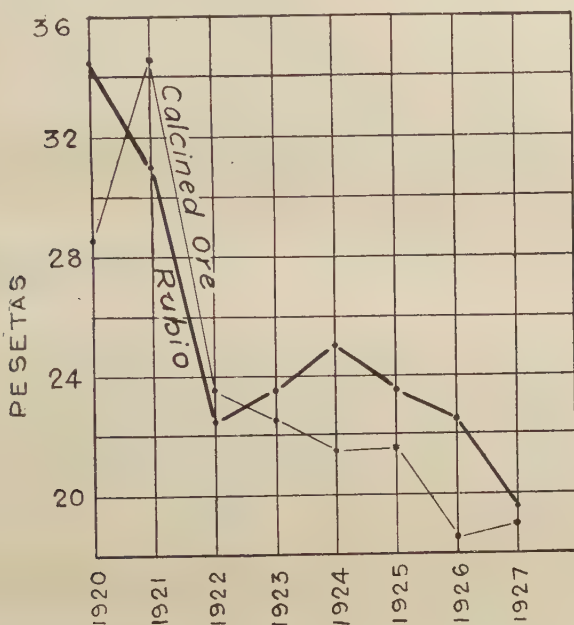
FIG. 20.—Price of Rubio Ore and of Calcined Ore, f.o.b.

Fig. 20 shows the variation in the price of first-class rubio and
spathic, f.o.b., from the year 1920 to 1927.

Insufficient attention has been given to the importance of
modern loading methods in Vizcaya. Shipowners, when sending
a ship, have from long experience a good knowledge of the condi-
tions at the loading staith at which the ship is to load. The rate
of loading is usually guaranteed at 500 tons per working day. If
the seller fails to load at this rate he pays demurrage at the rate of
2d. per ton per day on the total ore shipped. It will therefore
be understood that a company whose shipping arrangements are
well organised is able to save 2d. per ton on the freight.

1928—ii.   E

The mine owner usually disposes of his ore at a fixed price, all gains or losses, as also the premium to be paid, being placed to the account of the agent.

In the port of Bilbao the shipowner pays 0·50 peseta per ton to the Junta de Obras del Puerto, 0·75 peseta for maritime transport tax, and 0·35 peseta for *derrama* to the Shipowners' Association. The *derrama* is a tax which dates from the time of the European War, when the Government compelled shipowners to import wheat from the Argentine at reduced freights.

In some of the loading staithes in Santander, where loading is carried out by means of belts working at high speed, thus giving the ship a much quicker despatch, 1s. 5d. is often saved on the freights.

Prospects or Future of Bilbao Mines.—Various boreholes have been made on the eastern slope of the anticline which forms the ore deposit of the Bilbao district, with the idea of proving whether the limestone bed is mineralised or not. These holes were made in the vicinity of the Bilbao-Santander road, between Retuerto and Ortuella, but gave no positive results, in so far as at 500 m. depth the limestone bed had not yet been met, probably owing to the inclination of the strata. Borings were also made on the western side to test the syncline of Sopuerta and Galdames, with the same results.

This limits considerably the possibilities of the Bilbao deposits, likely as it is that the limestone bed would be met at a depth at which it would not pay to exploit it. On the other hand, between the San Miguel and Peñusco Mendiola faults results have been satisfactory, and, although incomplete, the borings allow a fair estimate of large masses of ore at reasonable depths. To the east of these faults and in the vicinity of the Peñusco Mendiola fault no borings have been made, and it is probable that a mineralised bed might here be cut at not too great a depth.

There are other parts of the district with possible ore, where no attempt whatever has yet been made to bore. In other words, the possibilities of Bilbao are still considerable.

The author hesitates to give definite figures for the ore reserves of the district, but tentatively one may reasonably estimate that present workings show a content of some 65 million tons, of which, say, 40 per cent. is probably spathic.

From borings made in virgin mines one deduces a reserve of some 40 million tons of ore, principally spathic, and a conservative addition of a further 60 million tons in unbored parts of the district may be supposed. These, together with the 200 million tons already extracted in the district, bring the total to 365 million tons when mining operations began.

The future of the district is dependent on the spathic ore. The conditions under which the ore has to be extracted, as compared with rubio, necessitate a larger consumption of explosives, but this is compensated for by the fact that the faces are much cleaner, and the general conditions favour systematic mechanisation. On the other hand, 40 per cent. more crude spathic ore has to be extracted than the amount of calcined ore obtained, but this also has its compensation in the higher iron content.

Comparing the behaviour of first-class rubio and first-class spathic in the furnace, it is to be noted that the latter shows higher loss in the flue, and its higher sulphur contents call for a more basic slag. Even taking into consideration these disadvantages, a calculation of the comparative furnace charges seems to indicate that the price of calcined spathic could be 20 per cent. higher than that of the rubio. This is not the case to-day, but it is to be supposed that, as time goes on, prices will be stabilised and that the relation of the price of calcined to the rubio price may reach the above percentage. Already one begins to observe an increased demand for calcined spathic. In the above comparison the calcined spathic has been assumed to have no further treatment and to be used alone. In practice this is not feasible, but the ore sinters very well, and if submitted to this treatment it could be used as the principal ore. If, for instance, 40 per cent. of it were submitted to sintering, the sulphur content could be reduced to, say, $0 \cdot 28$ per cent. The surcharge of 2 pesetas per ton incurred by this treatment is balanced by the reduction in sulphur contents and of flue losses.

BIBLIOGRAPHY.

RAMON ADAN DE YARZA : " Yacimientos metaliferos del pais Vasco Navarro en la
     geografia general del mismo."   Barcelona.   Alberto Martin.
RAMON ADAN DE YARZA : " Memorias de la comision del mapa geologico L892.—
     Descripción fisica y geologica de Vizcaya."
WILLIAM GILL : *Journal of the Iron and Steel Institute,* 1896, No. II. p. 36.
RAMON URRUTIA : *Revista Minera,* 1919, May 24.
RAMON DE ROTAECHE : " El criadero de hierro de Vizcaya."   *Boletin Minero,*
     1926, July 9.
EMILIO DE JORGE : " El Eoceno en Vizcaya," *Congreso Internacional de Geologia,*
     Madrid, 1926.
PABLO DE ALZOLA : " Ferrocarriles de via ancha y de via estrecha."   Madrid,
     1885.

DISCUSSION.

Mr. W. SIMONS (Member of Council) said that as one who was directly connected with the iron ore industry he had found the paper of very great interest. The author stated that it was supplementary to Mr. Gill's paper, but in Spain, as in all other countries, social changes had occurred and labour costs and taxation had increased, and, therefore, the old method of working by hand-labour, as described by Mr. Gill, had been supplanted by a system of mechanisation for the purpose of reducing the cost. The author had given a very able description of the changes that had taken place in that respect, on which he congratulated him heartily.

He desired specially to call attention to the very interesting chart included in the paper, which gave details of the production of iron ore. It would be observed that the rise in the output of iron ore coincided with the development of the steel industry in England. It was hardly necessary for him to tell the members that one defect of the Bessemer process was that it could not eliminate the phosphorus, and the only place at that time from which low phosphoric ores could be obtained in any quantity was Spain. Although English ironmasters claimed to be pioneers in the production of iron and steel, they were indebted to the enterprise of the mine owners in Spain for the manner in which they were able to supply England with iron ore during that period. It might be said that after 1900 there was a direct drop in the production, which some people might attribute to the diminished amount of ore available in Spain, but he did not think that was the case. He ventured to say that at that time the basic Bessemer process came into active operation, and therefore there was a much wider field of ore obtainable. He desired to place on record, however, that Great Britain was indebted to a large extent to the great assistance it had received from other countries during the early days of the steel industry.

From the technical point of view it would be observed that the author had raised a very important point—namely, that the future of the iron ore mines in Spain would be dependent upon supplies of spathic ore. That had been foreseen. Spathic ore was increasing in quantity, and it was necessary either to put down additional kilns or to get a larger output from the existing kilns. He confirmed the statement made by the author in the paper that the general manager and the staff of the Orconera Co. were exceptionally successful in the treatment that had been adopted by altering the base of the kilns, the admission of air and the method of discharging, thus preventing the formation of boulders, and thereby doubling the output of the kilns. They had thus made a substantial contribution to the success of the industry by showing how the cost of calcining could be materially reduced, a point of great value to all engaged in the industry. Another

important point he desired to mention was that it was more difficult
to work in a blast-furnace spathic ore containing 25 per cent. of very
fine material than to work such an excellent lumpy ore as the rubio
ore which was obtained in Bilbao. That difficulty had been faced
at the Cardiff works, as indicated by the author, by putting down a
sintering plant. That sintering plant had been operating for about
six weeks, the whole of the fines being taken out of the spathic and
other ores, and the improvement in the blast-furnace operation had
been most marked. The amount of flue-dust that was blown out of
the furnace had been reduced by 50 per cent., and there had been
a gradual improvement in the working of the furnace due to careful
sizing of the material. It was impossible to get good work from
a blast-furnace in which irregular material was employed. He had
been delighted to receive a cablegram saying that the improvement
was so marked that one of the blast-furnaces in operation at Cardiff
had produced another record, although it already held the record for
the country. The output during the previous week was 3700 tons,
which he put down directly to the adoption of the points set out in
the paper. All those engaged in the industry would have to take
into consideration the great importance of sintering and careful sizing
of the material in order to make the most of the fine material that was
now on the market.

Mr. F. W. HARBORD, C.B.E. (Past-President), said he had sincerely
hoped that the President-Elect, Professor Louis, who had a very
intimate knowledge of the mines in the Vizcaya district, would have
been present at the meeting that morning, but unfortunately he was
temporarily indisposed. He hoped that the members of the Institute
who resided in the district would take an active part in the discussion,
because obviously they knew very much more about the subject than
the members who came from England. There was only one question
he desired to ask. From his recollection of his previous visit to Bilbao
he believed that at that time little, if any, ore was washed, and he
would therefore like to know to what extent the proportion of ore
washed had increased during the last twenty years. The proportion of
ore washed had a very important bearing on its use in English works,
as, if the total quantity was large, it might be necessary to arrange for
sintering on a much larger scale if the washed ore consisted principally
of fines.

Mr. BALZOLA, in his reply, regretted that he had been unable to
attend the meetings personally through ill-health, but expressed his
gratification that his work had proved useful to the members on their
visit to Bilbao. He wished to record his gratitude to Mr. Simons for
the appreciative remarks which he had made on the paper, as well as
to the many members who had personally expressed their approval of
his work.

The results obtained by Mr. Simons at his sintering plant were extremely interesting, the subject being one of paramount importance to Bilbao. He would be glad if Mr. Simons would complete his information with further data, and give the comparative coke consumption with sintered and unsintered calcined ore.

In answer to Mr. Harbord, the author replied that the utilisation of " chirta " by mechanical washing commenced in Vizcaya some 35 years ago, about which time several small washeries were installed. The production had since greatly increased ; 20 years ago the proportion of washed ore was about 15 per cent. of the whole output, to-day it would be about 20 per cent. Most of the mine owners shipped their washed ore mixed with lumpy rubio ore. As the material to be washed in the province consisted now principally, in fact almost wholly, of proceeds from old dumps or of the more clayey portions of lumpy quarry products, the sizing was varied ; the proportion of fines below 15 mm. ranged between 15 and 20 per cent. in some mines, and between 60 and 70 per cent. in others. On an average the proportion might be taken as 40 per cent. below 15 mm.

EFFECTS OBSERVED IN QUENCHED LIQUID STEEL PELLETS AND THEIR BEARING ON BATH CONDITIONS.[1]

By J. H. WHITELEY, F.I.C. (Consett).

INTRODUCTION.

In judging the condition of a bath of steel and the degree to which the refining process has been carried, the smelter is guided by a variety of observations. The vigour of the boil, the condition of the slag, the appearance of a spoon sample, and its fracture when broken, all yield evidence to the practised eye. While the information thus derived is of great value, it is by no means complete, and the development of further tests would therefore be of advantage. It was with this object in view that the present investigation was undertaken. An attempt has been made to extend the use of the microscope in the study of steel, so as to include its manufacture in the furnace. Since little, if any, investigation in this direction appears hitherto to have been carried out, the effort must be regarded as explorative in character. Although much further work is needed, the results so far obtained indicate that the examination of quenched pellets can yield additional information on bath conditions.

THE SAMPLE AND ITS PREPARATION.

The method employed in sampling the molten steel is extremely simple. It aims at suppressing as far as possible effects which may occur as the metal freezes. A spoonful with a covering of slag is withdrawn from the furnace and poured from a height of about 2 ft. into cold water, 1 ft. or so in depth, contained in a small iron tank. As it impinges on the surface of the water the stream of liquid steel is broken up into a large number of globules

which, of course, solidify almost instantaneously.   Two or three, measuring about $\frac{1}{8}$ in. in diameter, are selected and mounted for examination in a holder of Wood's fusible alloy.   This may be done rapidly by filling a nickel crucible $\frac{5}{8}$ in. in diameter with the melted alloy and then immersing the specimens.   While the metal is solidifying they can easily be arranged in any desired position.   When the alloy has become rigid it is removed from the crucible and a surface prepared in the usual way by grinding and polishing.   The pellet sections may now be etched *in situ*; for this purpose the following two reagents are required :

(1) A 5 per cent. solution of picric acid in alcohol.

(2) Dufay's reagent, consisting of 100 c.c. of alcohol (95 per cent.), 10 c.c. of water, 1 grm. of copper chloride, $0 \cdot 5$ grm. of picric acid, and 1 to 3 c.c. of hydrochloric acid.

The examination of a large number of these quenched pellets has shown that several kinds of inclusions may be present, namely, sulphide, oxide, slag, and gas.   Further, a structural heterogeneity, often very pronounced, is revealed by Dufay's and other cupric reagents.   This usually takes the form of a network, a good example of which is seen in Fig. 27 (Plate XX.).   It will be convenient to discuss these features, together with the information they give on bath conditions, in the above order.   To identify the different inclusions a high magnification is required, owing to their extremely small size.

Sulphide Inclusions.

The sulphide is the lightest inclusion to be seen, its colour closely resembling that of iron sulphide in normally cooled samples containing little or no manganese.   A noteworthy feature is that the tint in the quenched pellets is not appreciably different even when $0 \cdot 5$ per cent. or more of manganese is present in the steel. Examples are given in Figs. 1, 2, and 7 (Plates XV. and XVI.). Proof that this light-coloured constituent is sulphide was obtained by means of the antimony-gelatin reagent, details of which have been given by the author.[1]   When a drop was placed on the surface of the specimen, red rings of antimony sulphide quickly formed round each particle.

[1] *Journal of the Iron and Steel Institute*, 1920, No. II. p. 145.

Sulphide inclusions occur almost entirely in the network disclosed by Dufay's reagent, but their distribution is by no means uniform, especially in mild steel samples. They frequently appear in clusters (Fig. 7), often widely separated. The inference to be drawn from this fact is that the whole of the sulphide is not in solution in the liquid metal, but exists as a separate phase in the form of minute droplets. That a substance precipitated from solution during freezing may be ejected to the boundaries by the growing crystallites and there coalesce to some extent in a small fraction of a second, as the present case requires, is perhaps possible, but not that it may further aggregate in patches often many grains apart. On these grounds it is reasonable to infer that the solubility of sulphide in liquid steel is extremely low, since particles can be seen in pellets containing less than $0 \cdot 03$ per cent. of sulphur. The likelihood of the existence of sulphide in the liquid steel " in the form of minute globules of an immiscible complex sulphide " was considered in Section IV. of the First Report on the Heterogeneity of Steel Ingots.[1] As will be explained in the next section, the occurrence of these sulphide inclusions in any quantity indicates that the steel is not overoxidised, for with an increasing oxide content they gradually disappear.

It may here be remarked that Giolitti[2] has advanced the hypothesis that manganese, when added to a bath of steel, acts as a flocculating agent, and so, by increasing the size of the inclusions, facilitates their removal. Confirmatory evidence of this effect has not been obtained in the investigation here recorded ; no difference in the size and distribution of the sulphide particles in quenched pellets of both open-hearth and electric steels, taken before and after the addition of ferro-manganese, could be detected in several samples examined.

Slag and Oxide Inclusions.

In examining acid steel pellets there is no difficulty in distinguishing between slag and oxide inclusions ; the oxide is somewhat lighter in colour, its tint being intermediate between

[1] *Journal of the Iron and Steel Institute,* 1926, No. I. p. 104.
[2] *Ibid.,* 1923, No. II. p. 35.

that of sulphide and slag.   Further, oxide particles are very minute and seldom exceed $\frac{1}{20,000}$ in. in diameter, while slag globules are usually much larger.   Examples showing all three together are given in Figs. 1 and 2.   In Fig. 1 the oxide is contained in the sulphide.   A useful method of identifying slag in acid steels is to immerse the polished specimen in a 2 per cent. solution of hydrochloric acid.   This reagent quickly dissolves oxide, which is chiefly in the ferrous state, and a cavity remains.   Slag inclusions become darker, but are not removed.   Unfortunately, the test fails with basic steels, owing to the solubility of the slag, and no other reagent suitable for the purpose has yet been found.   Globular slag inclusions of the size common to acid steels are, however, very rarely seen.   When present, they are of the same colour as oxide, and sometimes contain a lighter constituent which resembles sulphide (Fig. 13).   In acid steels the slag is probably derived from the hearth, the surface of which must be in a partially fused condition, especially in the later stages of the process.

A further aid to the identification of oxide in both acid and basic steels results from its association with the lighter-coloured sulphide.   This is due to the fact that at the temperature of liquid steel they are mutually soluble, but as the temperature falls separation of one of the constituents rapidly occurs, with the formation of a eutectic at about 950° C.[1]   The association of oxide with sulphide is seen in the following experiment.   Pieces of a mild steel containing 0·16 per cent. of sulphur were heated to a white heat in a magnesite crucible, and then completely melted by applying a small jet of oxygen.   Part of the liquid metal was then poured into water and the remainder on to a metal plate. It was found that the sulphur content had been reduced to 0·05 per cent.   Both portions contained a great number of oxide particles. In the air-cooled pellets these were surrounded by a border of eutectiferous sulphide, as shown in Fig. 8 (Plate XVI.).   In the water-cooled pellets the particles appeared to consist of a single phase ; the sulphide had evidently been retained in solid solution in the oxide.

The same effect was similarly obtained with a sample from a bath of over-oxidised low-carbon basic steel.   Sulphide-oxide inclusions were present in the air-cooled pellets, as shown in

[1] *Journal of the Iron and Steel Institute*, 1920, No. II. p. 145.

Fig. 5, while in the quenched specimens much less separation had taken place. By heating the latter to 950° C. and air-cooling it was markedly increased. This association of oxide and sulphide provides a useful method of judging the oxide content of a steel, for, if only light-coloured sulphide particles are to be seen in any quantity, it is clear that the amount of oxide present is at, or approaching, a minimum.

As with the sulphide, the greater number of the oxide particles are to be found at the boundaries of the cells revealed by Dufay's reagent. Fig. 3 shows a network of oxide and sulphide particles in an acid steel sample. Fig. 12 (Plate XVII.) illustrates the arrangement of oxide inclusions in quenched pellets of a sample of Armco iron which had been melted in an oxidising atmosphere. The cellular structure of the pellets brought out by Dufay's reagent is seen in Fig. 14. This manner of distribution only applies to particles of the smallest size ; the larger slag particles are scattered at random throughout the metal and seldom occur in the cell walls.

Although it does not seem possible to obtain direct proof that these slag and oxide inclusions are present in the molten metal and are not taken up in sampling, the validity of the assumption appears justified from several considerations. It may be mentioned, in the first place, that a certain amount of slag is of necessity withdrawn with the metal, and frequently quite large masses are found entangled in the pellets. An example is given in Fig. 13. Yet, in the steel itself, very few minute inclusions of the type shown in Fig. 3 may be seen. On the other hand, examples apparently free from entangled slag have repeatedly been observed in which minute slag particles were excessive. Furthermore, as regards acid steel at any rate, all the evidence so far obtained shows a correspondence between the quantities of slag and oxide in the pellets at tapping and the silicates in the finished steel.

There is, of course, the possibility that contamination with oxide may occur by a reaction of the steel with the air or water during its passage through them. In either case it is to be expected that the amount taken up will depend upon the length of time during which the molten metal is in contact with the medium. The experiment was therefore tried of pouring two spoonfuls of the same metal into water from a height of 6 ft. and

1 ft. respectively. Several such tests were made, and in each instance no difference between the oxide contents of the two samples could be detected. A similar result was obtained on comparing samples taken with and without a covering of slag. In the latter, the short exposure of the metal to the air before pouring did not appreciably increase its oxide content.

Another experiment was made as follows. Two samples were withdrawn ; one was poured into carbon tetrachloride and the other into water. The pellets given by the carbon tetrachloride quench were found to be highly carburised in places, but there appeared to be no difference between the number of inclusions in the two samples. An example showing the penetration of the massive carbide is seen in Fig. 23 (Plate XIX.). This experiment was also repeated several times with the same result, from which it is concluded that the amount of oxide taken up by the molten metal during the small fraction of a second it is in contact with either water or steam is negligible.

It may thus be inferred that the slag and oxide to be observed in the pellets were actually present in the steel in the furnace. This conclusion is quite in accord with the fact that well-refined steels contain no visible oxide particles. Many samples of both electric and open-hearth steels have been examined, and in all cases where the metal has been thoroughly deoxidised by the attainment of correct slag conditions oxide particles were absent. Further, it has been repeatedly noticed, especially in making non-piping steels, that the amount of oxide in the pellets increased considerably as the carbon dropped below about 0·2 per cent. Scarcely any visible particles could be detected in samples taken during the boil in the acid process, but as the carbon approached 0·10 per cent. the quantities of slag and oxide inclusions sometimes became considerable. A still greater increase was frequently noticed in the basic process, although here a little more oxide was usually present with the sulphide in the higher carbon samples. When the carbon is nearly all removed, as in the manufacture of ingot iron and similar material, excessive quantities of oxide are usually to be seen. Clearly this increase in the number of inclusions as the carbon content of the bath is reduced is, of itself, a strong argument that the method of sampling is reliable.

In the previous section evidence was given which indicated that the sulphide existed as separate particles in the molten steel. Since oxide is invariably associated with sulphide in the pellets, it seems reasonable to infer that the visible inclusions were also undissolved in the bath. As a tentative explanation of their presence, it is suggested that just beneath the slag the metal becomes slightly supersaturated with oxygen, and on passing downwards to a somewhat cooler region the excess is thrown out of solution. If sufficient carbon or other metalloid is present, the precipitated oxide is quickly removed, but otherwise it begins to accumulate. The above observations lead directly to the conclusion that the frequent basic practice of eliminating most of the carbon and then recarburising in the ladle to the extent required does not ensure the cleanest steel. The more difficult method of " catching the carbon as it falls " is to be preferred.

Gas Inclusions.

Minute spherical cavities of the type shown in Fig. 6 form one of the most striking features in samples taken from a bath that is either killed or in very good condition. In general, it may be said that their number increases with the refinement of the steel. Under a low power these cavities may easily be mistaken for non-metallic inclusions. In size they seldom exceed $\frac{1}{4000}$ in. in diameter, and their distribution appears to be quite haphazard. Their retention does not depend upon the rapidity of cooling, for many are to be found in ordinary spoon samples from a dead melt. That they are not due to the dislodgment of spherical particles of slag during polishing is evident from the fact that they are not to be found in over-oxidised steels, even if many slag inclusions are present. Moreover, samples of well-refined steel showing large numbers of the cavities have been obtained in which very few slag particles were to be seen. These cavities must, therefore, be gas bubbles, and the further inference to be drawn is that they were present in the molten metal ; otherwise, there appears no reason why they should be absent from more oxidised steels. The fact that such samples are free from them may be due to the liberation of carbon monoxide from the body of the metal in the bath. It is to be expected that large gas

bubbles will sweep much smaller ones away with them as they rise to the surface. The presence of the minute cavities would thus seem to indicate that oxidation of the carbon at the time of sampling has been practically confined to the interface between slag and metal.

Pellets taken from a bath having an open boil usually consist of hollow shells unless they are of very small size. This formation of blown pellets is due to the reaction between the carbon and the oxide in the metal at the moment of freezing, for pellets given by carbonless iron when melted in an oxidising atmosphere are always solid, except for a small contraction cavity at the centre. They can be obtained hollow by the addition of some carbon to the melt. Consequently this effect is, of itself, a sure indication of the oxidised condition of the metal. Samples of killed steel are also solid, yet, even in these, a separation of the crystals may sometimes be observed, as shown in Fig. 9. As a rule these internal cracks are much more numerous in hollow samples. They are usually to be found in the network revealed by Dufay's reagent, and appear to be the result of the liberation during freezing of part of the occluded gases. That they are not due to the action of steam or to strain in quenching was proved by their presence in pellets obtained by pouring a few drops of liquid steel on to a cold plate. The extent to which these cracks occur may have an important bearing on the heterogeneity of the ingot, for the result of an expulsion of minute amounts of gas from the growing crystals would be a slight displacement of the mother liquor from its natural positions. Such an effect would tend to be cumulative.

THE CELLULAR STRUCTURE.

As previously indicated, Dufay's reagent is very suitable for the development of this structure. In etching, two or three drops are placed on the surface and allowed to remain there until a visible coating of copper has been deposited ; the specimen is then washed and dried. The structure is not confined to mild steels ; it may be seen well developed in samples containing over 1 per cent. of carbon. Its definiteness varies considerably in different cases. Very pronounced effects are given by pellets from baths that have been brought to a " dead melt " condition.

PLATE XV.

FIG. 1.—Slag, oxide and sulphide in acid steel. ×1500.
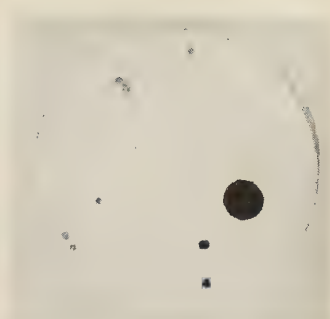
FIG. 2.—Slag, oxide and sulphide in acid steel. ×950.

FIG. 3.—Oxide inclusions in acid steel. ×400.
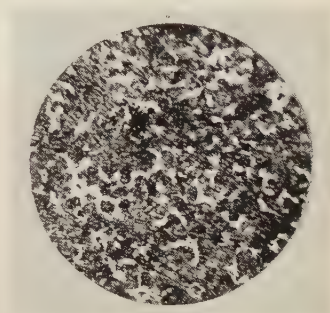
FIG. 4.—Broken network; basic steel (combined carbon 0·2 per cent.). ×150.
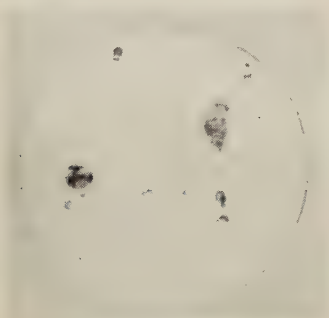
FIG. 5. — Sulphide - oxide inclusions. ×1500.
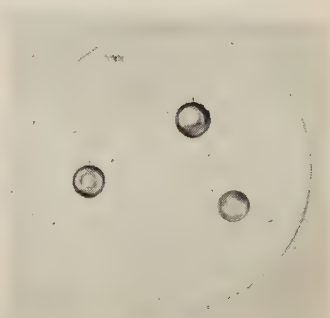
FIG. 6.—Gas inclusions in dead melt sample. ×950.

PLATE XVI.
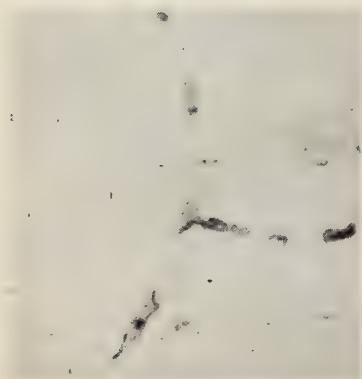
FIG. 7.—Cluster of sulphide-oxide inclusions. ×1500.
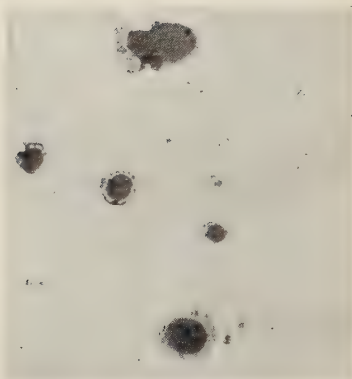
FIG. 8.—Iron-oxide and sulphide-oxide eutectic. ×950.

FIG. 9.—Intergranular crack. ×850.
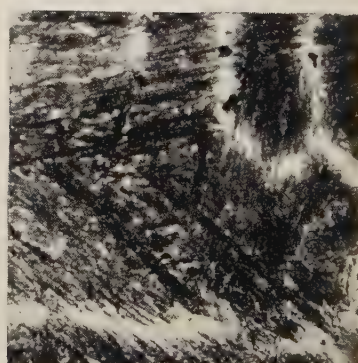
FIG. 10.—Martensite crossing cell walls. ×950.

PLATE XVII.

FIG. 11.—Oxide in electrolytic iron pellets. ×400.

FIG. 12.—Oxide in Armco iron pellets. ×400.
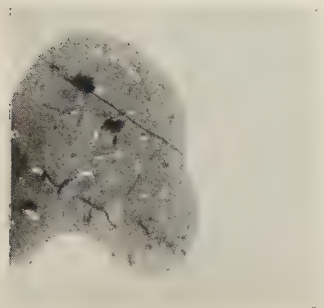
FIG. 13.—Basic slag inclusion. ×950.
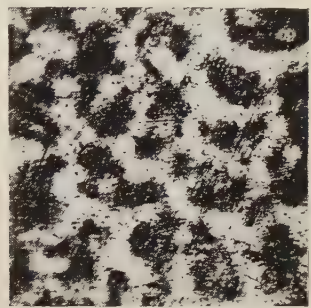
FIG. 14.—Cellular structure in Armco iron pellets. ×140.
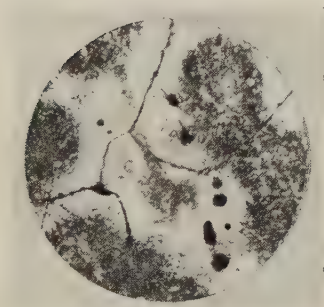
FIG. 15. — Grain boundaries crossing network. ×950.
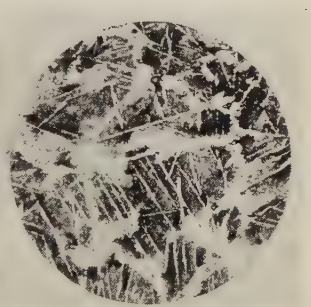
FIG. 16. — Cementite needles crossing network. ×360.

PLATE XVIII.
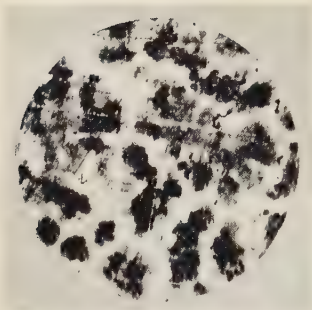
FIG. 17.—No. 20, after 2 min. at 1050° C. ×140.
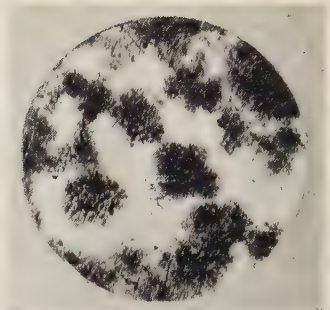
FIG. 18.—No. 20, after 2 min. at 1200° C. ×140.

FIG. 19.—Dendritic structure in pellets (combined carbon 0·35 per cent.). ×140.
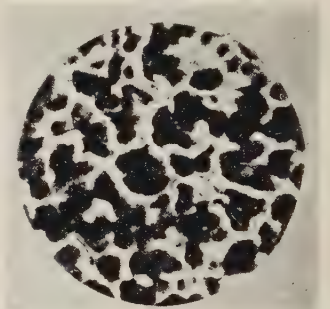
FIG. 20. — Cellular structure. ×140.
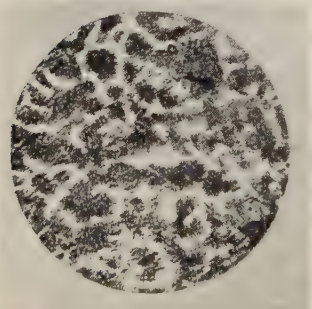
FIG. 21.—Structure in quenched pellets. ×150.
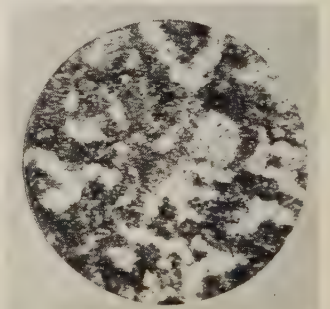
FIG. 22.—Structure in air-cooled pellets. ×150

PLATE XIX.

FIG. 23.—Massive cementite in car-
burised pellet. ×140.

FIG. 24.—Irregular network. ×150.

FIG. 25.—Skin of ingot. ×65.
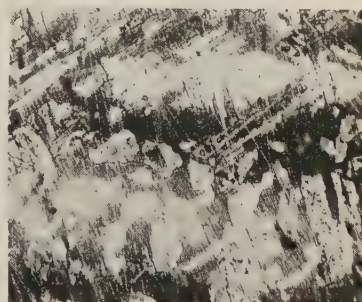
FIG. 26. Same as Fig. 25, further
in. ×65.

PLATE XX.

FIG. 27.—Regular cellular structure. × 75.
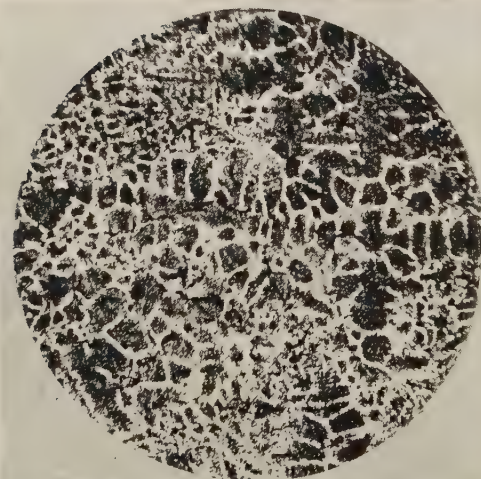
FIG. 28.—Irregular cellular structure. × 75.

Figs. 20 and 27 (Plates XVIII. and XX.) show the structure observed under different magnifications, in pellets taken from an electric furnace after the addition of manganese and silicon.   The steel had the following composition : Carbon $0 \cdot 34$, silicon $0 \cdot 30$, phosphorus $0 \cdot 04$, sulphur $0 \cdot 03$, and manganese $0 \cdot 59$ per cent. The clear outline and fairly uniform size of the cells is very marked.   If the bath is not in good condition the structure is often indistinct, and in places may be entirely missing, especially in the larger pellets.   Moreover, the cells may vary greatly in size. Examples are given in Figs. 24 and 28 (Plates XIX. and XX.). Sometimes a broken effect is obtained, as shown in Fig. 4 ; in such cases repeated cloth-polishing and etching will usually bring out more of the network.   Early observations seemed to indicate that the condition of the bath could be judged by the appearance and definiteness of the structure alone, but subsequent work has not altogether confirmed this conclusion.   Occasionally, a moderately good network is found in samples known to be over-oxidised.   This much at least may be said, however, that an ill-defined structure has not yet been given by a thoroughly deoxidised steel.

On a close examination of the cell walls in a properly etched specimen, a thin central zone more resistant to the action of the reagent may often be seen.   From the appearance of this cored structure it was inferred that the inner zone had formed first and that the speed of quenching had not been sufficient to prevent a slight outward diffusion afterwards.   An experiment was therefore undertaken in order to obtain some idea of the rate at which diffusion did occur at high temperatures.   Three pellets of the sample with the network shown in Fig. 20 were heated for 2 minutes at 1050° C., 1200° C., and 1350° C. respectively, and quenched in water.   The effects produced at 1050° C. and 1200° C. are illustrated in Figs. 17 and 18 (Plate XVIII.), from which it is clear that the rate of diffusion rapidly increases with the temperature.   At 1350° C. diffusion had still further progressed.   It was also seen that at 1050° C. a markedly cored structure had formed.   This result, of itself, seemed sufficient to justify the above conclusion.   A further confirmation was obtained by allowing some pellets of mild steel to set on an iron plate and comparing the structure in these with that in a quenched sample

of the same steel. The two are illustrated in Figs. 22 and 21 respectively. In the former the cell walls are broken and very broad ; it will also be noticed that the network is on a larger scale than that in the quenched steel.

That the cellular structure denotes heterogeneity is certain. It has been observed repeatedly that ferrite first appears in the cell walls in cases where the rate of cooling in the water has been retarded sufficiently to allow a separation to begin. This fact indicates that the network is formed of rejected mother liquor, for the same effect can be shown to occur in the segregated areas of ordinary cast steel. The presence of the sulphide in the cell walls also points to the same conclusion. From this it follows that the network defines the boundaries of the primary crystallites. In this connection it may here be remarked that the grain boundaries in the quenched specimens have no connection with the network ; this is plainly shown in Fig. 15 (Plate XVII.). Similarly, in mild steel specimens, the martensite needles frequently cross the cell walls, as seen in Fig. 10 (Plate XVI.). It would thus appear that a recrystallisation occurs in the solid metal during quenching. The same thing was noticed in one or two pellets which had been quenched in carbon tetrachloride. Sufficient carbon had diffused well into the interior to cause the deposition of needles of hypereutectoid carbide. Here also, in many places, the needles crossed the cell walls, showing that the austenite grain boundaries were not located there. An illustration is given in Fig. 16.

There is, of course, the possibility that the network structure is the result of heterogeneity in the molten steel. The hypothesis that liquid metals are not homogeneous but contain a concentration of impurities in the form of a foam has been advanced by Quincke.[1] This explanation seems at least plausible, not only when the speed of freezing is considered, but also because of the variation in the size of the cells sometimes observed. If such is the case it appears reasonable to expect that the network in hollow pellets would show distortion due to gas pressure in the neighbourhood of the cavity. No indication of such an effect has been noticed. Again, a few dendrites are occasionally to be seen. These must have crystallised during freezing, and if two happen to be in parallel

[1] *Internationale Zeitschrift für Metallographie*, 1912, vol. iii. pp. 23–26.

juxtaposition, as shown in Fig. 19 (Plate XVIII.), the segregate between them is continuous with the cell walls, and of exactly the same character. It cannot be claimed, however, that these facts are decisive; conclusive evidence for or against the theory is difficult to obtain. If, as seems more likely, the structure is due to selective freezing, the ejection of the segregate by the growing crystallites must occur with great rapidity, for a strong network may be present in pellets weighing less than 0·02 grm. To produce a structure such as that shown in Fig. 27, crystallisation would appear to start simultaneously from a large number of almost regularly spaced centres, for otherwise dendritic growth would occur. The network of segregate thus formed will at once begin to diffuse back into the purer parts; variations in the rates of diffusion of the segregating elements will then account for the extent to which the definiteness of the structure is preserved in equal-sized pellets of different steels.

The particular elements which give rise to the structure have not yet been ascertained. Oxygen does not appear to be essential, for, as previously stated, the best effects are to be seen in the most deoxidised steels. Moreover, samples of electrolytic iron containing 0·004 per cent. of phosphorus, when melted in an oxidising atmosphere, did not show the structure in the quenched pellets. This conclusion is in complete agreement with the recent work of Sauveur [1] and also of Tritton and Hanson,[2] who found that cupric reagents failed to reveal any heterogeneity due to oxygen. It is of interest here to note that the numerous oxide particles in the quenched pellets of electrolytic iron were almost uniformly distributed, as shown in Fig. 11 (Plate XVII.), whereas they were in network formation in a sample of Armco iron similarly treated (Fig. 12). The cellular structure of the latter is seen in Fig. 14.

Considerable attention has also been given to phosphorus, since this is known to be a segregating element, but the definiteness of the structure has not been found to depend upon its content in the steel. The rapid rate at which diffusion occurs even at 950° C. would, of itself, indicate that no important concentration of phosphorus occurs in the cell walls. Further, a network very

[1] *Journal of the Iron and Steel Institute*, 1925, No. II. p. 313.
[2] *Ibid.*, 1924, No. II. p. 120.

similar to that present in the remelted Armco iron (Fig. 14) was
given by a bath sample of basic steel containing not more than
0·001 per cent. of phosphorus when melted in an oxidising
atmosphere and quenched. In this instance 0·02 per cent. of
carbon was left in the metal, but no manganese or silicon.

In the First Report of the Committee on the Heterogeneity
of Steel Ingots [1] it was shown that just beneath the skin of an
ingot there exists a layer of small crystals "almost without
visible structure." The foregoing observations provide an
explanation of this effect. It is clear, in the first place, that the
chilling action of the mould will be less severe than that of cold
water, and, since quenched pellets show heterogeneity, it should
be produced also during the solidification of the steel forming the
skin of an ingot. That it is not subsequently found is no doubt
due to the small size of the crystallites and to the speed at which
the segregate is dispersed by diffusion at high temperatures. The
persistence of segregate will depend upon these two factors.
Judging from the experimental results given on p. 65, there
should be ample time for the segregate enclosing the small crystal-
lites in the outer zone of a plain carbon steel ingot weighing several
tons to become uniformly distributed as it cools to about 900° C.
Further in, where the larger columnar crystals begin to appear,
the distance through which diffusion must proceed in order to
produce homogeneity rapidly increases, and, as a consequence,
evidence of heterogeneity can be found. This was clearly seen
in a section taken from the lower part of an 8-ton ingot of killed
steel. The analysis of the steel was as follows : Carbon 0·4,
silicon 0·08, phosphorus 0·024, sulphur 0·021, and manganese
0·80 per cent. For a distance inwards of approximately $\frac{1}{3}$ in.,
the steel appeared to be nearly homogeneous when etched with
Dufay's and other cupric reagents ; an illustration is given in
Fig. 25 (Plate XIX.). Then the remains of dendritic segrega-
tion began to be apparent, as shown in Fig. 26. Still further
in, the dendrites increased in size and their outlines became more
distinct.

[1] *Journal of the Iron and Steel Institute*, 1926, No. I. p. 108.

SUMMARY.

A sample of the bath is obtained by pouring the liquid metal into cold water.   The quenched pellets thus formed are examined microscopically.

The particular features to be noted are : (1) Sulphide particles ; (2) slag and oxide inclusions ; (3) gas cavities ; (4) structural heterogeneity revealed by certain cupric reagents.   It is shown that certain deductions as to bath conditions, especially in regard to its oxide content, can be drawn from these observations.

The evidence indicates that sulphide of iron is, at most, very slightly soluble in liquid steel.   In steel not completely deoxidised, oxide particles may be seen.   They are usually associated with the sulphide, and tend to increase in number as the carbon drops below $0 \cdot 20$ per cent.

The presence of minute spherical cavities indicates good bath conditions.

The heterogeneity usually takes the form of a cellular network. The most sharply defined and uniform effect is given by thoroughly killed steels.

CORRESPONDENCE.

Dr. A. McCance (Glasgow) wrote that he would hesitate to subscribe to Mr. Whiteley's view that iron sulphide particles existed as such in liquid steel. The freezing-point diagram, for instance, of FeS and Fe, while by no means complete, was sufficiently well established to show that this view clashed with existing knowledge. With MnS it certainly was possible, and he hoped shortly to publish work which indicated that the effect of MnS could only be explained theoretically by assuming a limited solubility.

One factor, however, seemed to have escaped Mr. Whiteley. In taking a sample from the furnace a relatively cold spoon was necessarily used, and in the transfer from the furnace to the quenching bath sufficient cooling could take place to precipitate from solution those compounds which were slightly soluble before the actual pouring took place. There did not appear to be any doubt that the particles seen in the samples did actually exist in the steel, though Mr. Whiteley's conclusion that they were present in the bath as individual particles was not, in his opinion, correct. The great increase in the number of the particles as the carbon fell below $0 \cdot 20$ per cent. was a fact which he (Dr. McCance) could support from his own experience and work, and it was in accordance with the theory of the reactions taking place. The relative freedom from inclusions of steel made so that the carbon was caught coming down was another expression of the same law which could be expressed in the form :

$$FeO \times carbon = constant.$$

At $1530°$ C., the value of that constant, as calculated by him (Dr. McCance), was $0 \cdot 060$ when those constituents were expressed as percentages. The very great increase which took place when that carbon was low was very illuminating and explained many other observations.

There was, however, the possibility that the grey inclusions seen in the pellets were manganese silicate. That had the same colour as the sulphide, and had the unfortunate property also of dissolving sulphides so that it reacted to sulphur tests. It was thus a very misleading constituent; and it was to be hoped that Mr. Whiteley would continue his work, as there was still much to elucidate.

The Author replied that he was pleased to have Dr. McCance's remarks, particularly as the subject of the paper was one on which Dr. McCance was an acknowledged authority. He gathered that while Dr. McCance agreed that the inclusions observed in the pellets were actually present in the liquid steel as it set, he did not think they were

also present at a slightly higher temperature in the bath itself, owing to increased solubility. That certainly was a fair criticism, and he (Mr. Whiteley) admitted that he had not given sufficient attention to the point in the paper. Absolute proof was not possible by the method of taking quenched pellets, but the fact that he had repeatedly observed the inclusions in samples from very hot electric steel taken before the finishing slag was made seemed to favour strongly their presence. Further, he had not observed so far that the number of inclusions to be seen was at all dependent upon the temperature of the bath.

With regard to Dr. McCance's other point that the lightest constituent might easily be silicate of manganese and not sulphide of iron, he (Mr. Whiteley) failed to see how that compound could be present in a pure form in any of the steels examined. Moreover, many of them contained little more than a trace of manganese, and in such cases, at any rate, he thought that the presence of a pure silicate of manganese was out of the question. It would almost certainly be associated with silicate of iron, and, as far as he had observed, sulphide of iron was not soluble to any appreciable extent in the double compound. He nevertheless fully agreed with Dr. McCance that there was still much to elucidate, and he looked forward with interest to the publication of the further work which Dr. McCance was doing.

THE USE AND INTERPRETATION OF THE TRANSVERSE TEST FOR CAST IRON.*

By J. G. PEARCE, M.Sc. (Eng.)
(British Cast Iron Research Association).

Introduction.

The transverse test remains by far the simplest and most generally used test for cast iron. It can be made with little expenditure of time on a simple unmachined bar on a cheap and easily manipulated machine. The breaking load and deflection figures obtained are readily understood.

Square and rectangular bars have hitherto been commonly used for this test, but the recent British Engineering Standards Specification for grey cast iron [1] (No. 321, 1928) specifies for the first time in this country a cylindrical transverse bar. A greater degree of uniformity in results from similar bars of the same composition is assured if they are skin-machined, as minute skin-fissures and cracks may induce premature fracture in particular bars, and hence lead to erratic results, particularly from green-sand moulds. Since the outer layers of the bar are the strongest, the removal of more metal than is required to give a clean unbroken surface will in ordinary irons lead to a reduction in strength. Skin-machining, on the other hand, for the reason given, is generally found to increase rather than diminish the strength. Machining invariably results in improved deflection.

Current methods of using the results of the transverse test do not yield the whole of the information that this test is capable of giving, and the object of this paper is to suggest an alternative method of treatment.

A method frequently used in foundries and engineering shops is to report the actual breaking load, irrespective of the actual section, on the assumption either that the cast and nominal sizes are identical or that small variations between them do not cause

appreciable error. Since it is virtually impossible accurately to
cast a specified diameter, and since strength changes very rapidly
with small dimensional changes, this method is open to grave
errors, and may indeed give results which are contrary to the
facts. This mode of expression also precludes comparison be-
tween transverse and other specific stresses, such as tensile,
compression, shear, and torsion, or between transverse bars of
other shapes and sizes of the same material.

The method more commonly used in general working and
in technical literature, and usually recommended in text-books, is
that of converting by formula the breaking load at the cast size
into a breaking load at the nominal or specified size. This pro-
cedure cannot be justified except for very small variations, and
the nature of the error involved can be seen by a consideration
of the rupture modulus as a criterion of transverse strength.

MODULUS OF RUPTURE.

The formulæ for the strength of cast-iron transverse bars are
based on the hypothetical case of the weightless, end-supported,
centrally-loaded beam. For supports L in. apart and a central
load of W lb., by beam theory the bending moment at the centre
is $\frac{WL}{4}$. The resistance offered by the beam depends upon its
size and shape, and may be expressed as fZ, where f is the specific
resisting stress set up in the beam and Z is a constant for a given
bar (the section modulus), taking into account the size and shape
of the section. Within the elastic limit $fZ = \frac{WL}{4}$. The formula
ceases to be strictly true when the elastic limit is passed, but it
is convenient to measure the stress f at fracture by means of the
value $\frac{WL}{4Z}$. The stress f then becomes the so-called modulus of
rupture, although it might preferably, if more clumsily, be termed
the " ultimate bending strength " (U.B.S., similar to ultimate
tensile strength, U.T.S.) or " ultimate breaking strength by
bending." For a standard bar $\frac{L}{4Z}$ is constant, and then $f = KW$.
For accurately cast bars the conversion from breaking load to
rupture modulus is thus simple, and a straight-line graph can be

used. This conversion, of course, does not hold for bars not cast or machined accurately to specified size, for the modulus Z depends upon bar dimensions. Graphs can, however, be readily prepared covering variations in diameter of cylindrical bars, and the arithmetical objection is then removed.

The modulus of rupture may be regarded as a criterion of the bending strength of a particular bar, for it takes into account the dimensions of the bar itself. It affords a means of comparing the strengths of similar bars of different compositions and of different bars of similar compositions. The rupture modulus has the greatest significance as a simple means of determining a change of strength with section. It is a useful index to the influence of rate of cooling. The conversion procedure usually recommended for obtaining the strength of a cast bar in terms of the dimensions of a standard bar is based on the following reasoning:

Take, for example, the standard rectangular bar of breadth b and depth d; the modulus $Z = \dfrac{bd^2}{6}$,

whence
$$f = \frac{3WL}{2bd^2}.$$

Consider a cast bar of actual breadth b_1 and actual depth d_1 breaking at W_1.

Then
$$f = \frac{3W_1L}{2b_1d_1{}^2}.$$

Hence
$$\frac{3WL}{2bd^2} = \frac{3W_1L}{2b_1d_1{}^2},$$

from which the required load W for the specified dimensions b and d becomes

$$\frac{W_1bd^2}{b_1d_1{}^2}.$$

Alternatively, for the new standard round bars (B.E.S.A. Specification 321, 1928) of diameter d,

$$Z = 0\cdot0982d^3, \text{ and } f = \frac{WL}{0\cdot39d^3}.$$

If the cast diameter is in fact d_1 breaking at W_1,

then
$$f = \frac{W_1L}{0\cdot39d_1{}^3}.$$

Hence the required breaking load W for a standard diameter d is

$$\frac{W_1d^3}{d_1{}^3}.$$

The fallacy involved in the above reasoning lies in the assumption that f remains the same for the cast as for the specified

diameters.   This might be true for homogeneous materials, but
is not true for cast iron.   The closer the cast to the specified size
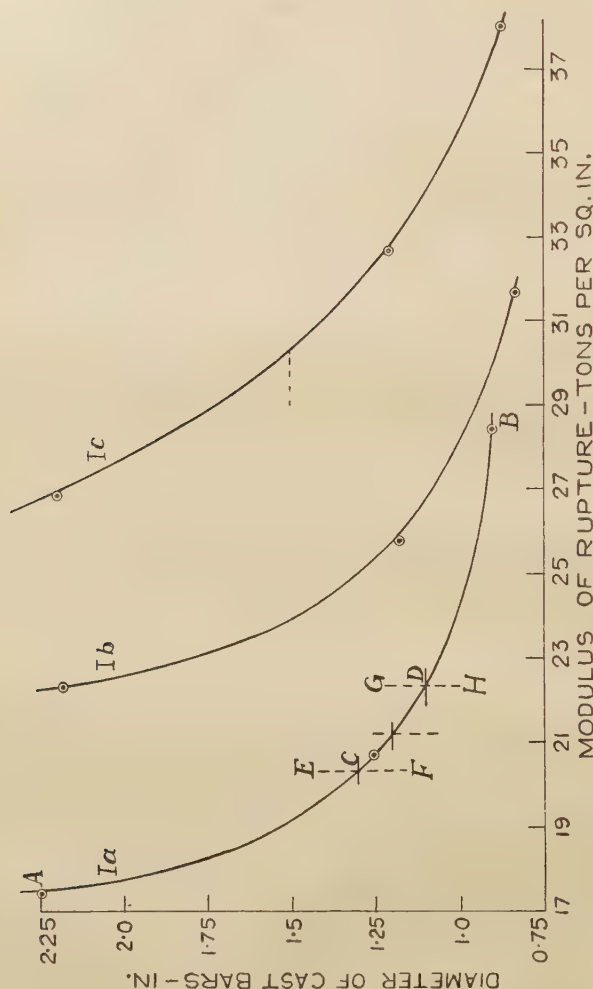
Fig. 1.—Variation of Rupture Modulus with Diameter.

the smaller is the error involved, but for ordinary casting toler-
ances the variation is too great to be ignored.   Fig. 1 shows an
illustrative case in which the three diameters of standard cylin-
drical bars are plotted against actual rupture moduli for three
series of bars, each series being cast in a different foundry.   The

analyses are given in Table I. It is generally understood among founders that the specific strength of a cast bar in a given mixture

TABLE I.—*Chemical Analyses of Bars.*

Bar Series.	Analysis.				
	Total Carbon. %	Silicon. %	Manganese. %	Sulphur. %	Phosphorus. %
1a	3·37	1·90	0·68	0·10	0·76
1b	3·42	1·55	0·55	0·08	0·49
1c	3·28	1·03	0·45	0·10	0·63
2a	Engineering iron of unknown composition				
2b		,,	,, ,,	,,	
2c	...	1·34	0·57	0·16	1·00
4a	3·13	2·64	0·43	0·09	1·18
4b	3·31	2·08	0·78	0·11	0·98
4c	3·08	2·07	0·37	0·15	1·04
5a	4·20	2·83	0·69	0·06	0·44
5b	3·26	2·91	0·41	0·06	1·23
5c	3·52	2·52	0·70	0·06	0·94
5d	3·33	2·78	0·62	0·07	1·10
5e	3·51	2·90	1·17	0·07	1·15
6a	3·86	1·13	0·90	0·05	0·16
6b	3·68	1·93	0·85	0·08	0·19
6c	3·27	1·81	1·10	0·05	1·14
6d	3·60	0·75	0·70	0·10	0·30
6e	2·73	2·41	0·71	0·10	0·19
8a and 8b	3·52	2·10	0·60	0·10	0·34
8c	3·35	2·15	0·65	0·07	0·47
8d	3·53	1·70	0·85	0·11	0·44
8e	3·29	1·10	0·95	0·06	0·11

diminishes as the diameter of the cast bar increases. The actual nature of the variation for three typical irons is shown in Fig. 1. While these curves are fixed by no more than three points, corresponding with the standard bar diameters used, there is no reason to suppose that the variation is otherwise than continuous over the range shown. If, then, the rupture modulus varies continuously over the range 2·25 in. to 0·8 in. in diam., that is, from A to B in Fig. 1a, then it must vary over an ordinary casting tolerance, say, from 1·3 in. to 1·1 in., that is, from C to D in Fig. 1a, for a nominal 1·2 in. diameter bar. The ordinary conversion formulæ assume that the modulus is constant over this range—*i.e.* that it follows the line EF for oversize or GH for undersize bars, instead of CD. An undersize bar by conversion

methods always gives better, and an oversize bar always gives worse, standard bar figures than should be the case. .Not only is the present conversion method erroneous, but where the bending strength follows a curve such as *AB,* no simple conversion will enable the modulus for one diameter to be utilised for calculating that for another diameter. The magnitude of the error naturally depends upon the slope of the curve as well as upon the difference between cast and nominal sizes. In the case shown in Fig. 1*a* the oversize bar 1·3 in. in diam. has a modulus of 20·5 tons per sq. in., and the undersize 1·1-in. diam. bar a modulus of 22·3 tons per sq. in. The 1·2-in. bar has a modulus of 21·2 tons per sq. in.

It is therefore suggested that the true criterion of transverse strength is the modulus of rupture determined for the actual bar section, measured at the point of fracture. The lack of any simple conversion may appear to create difficulties, but no purpose is served by ignoring facts. It will be shown later that many advantages accrue from testing bars over a range of sizes rather than of one size, as this enables the characteristic curve to be determined over the range.

Change of Strength with Size.

The characteristic curve connecting strength with diameter, which, it may be noted, can also be obtained for tensile, compression, shear, and torsion as well as transverse tests, has been obtained for a variety of irons, the results of three of these being shown in Fig. 2, and the corresponding analyses in Table I. Sometimes the curve is concave upwards, as shown in Fig. 1, sometimes concave downwards, or straight with varying angles of slope, as shown in Fig. 2. These variations confirm ordinary founding experience, for, according to conditions of composition and rate of cooling, some irons have a core almost as strong as the outer envelope, while others, being highly graphitised irons with a ferritic centre, have a core of very low strength. In the latter, the strength falls away quickly as the diameter increases. The difficulty of predicting the character of the curve for any iron at this stage makes any mathematical treatment impossible. Endeavours have been made, for instance, to determine experi-

mentally a factor which could be used for obtaining the strength of one size of bar from that of another size, but while this may serve for one mixture and melting régime, it would not necessarily hold for others.[2]

The bars fixing the points of any one curve in Figs. 1 and 2 were all poured at the same time from the same mixture, but, as will be seen from Table I., the mixtures differ from curve to
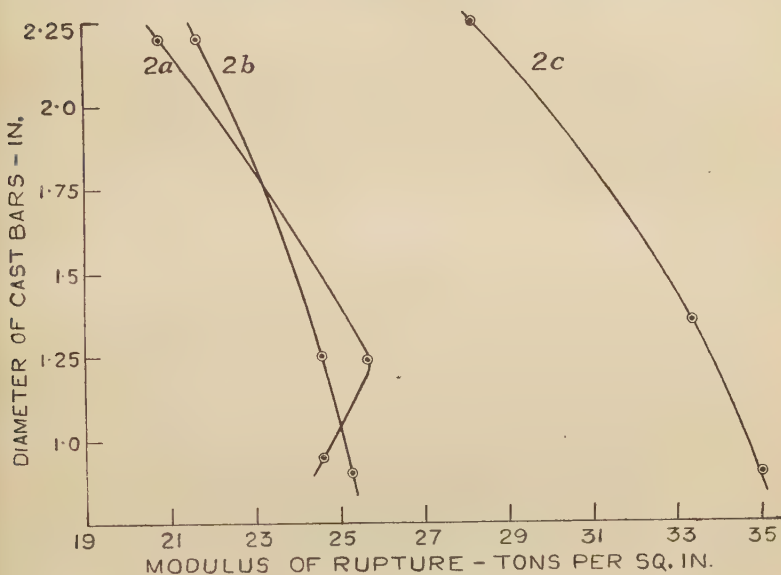
FIG. 2.—Variation of Rupture Modulus with Diameter.

curve. Naturally an iron intended for thin castings of high silicon and total carbon content will show low strength in a thick section compared, for example, with an iron intended for heavy, hard, engineering castings. Each is suitable in its particular application, and the advantage of a range of test-bar thicknesses for each type is referred to more fully below.

It has been suggested above that once the characteristic curve has been obtained the strength of any particular bar can be predicted by interpolation. Thus, in Fig. 1c, a bar 1·5 in. in diameter of the same material cast under the same conditions would have a rupture modulus of 30·3 tons per sq. in.   Care,

however, must be exercised in extrapolation. Up to date, only a limited experience has been gained from very heavy bars, for which the span has to be increased to obtain an easily read deflection. It has also been found that in bars of the same material cast at the same time, the modulus of rupture increases and the deflection diminishes as the span diminishes. Similarly, the modulus diminishes and the deflection increases as the span
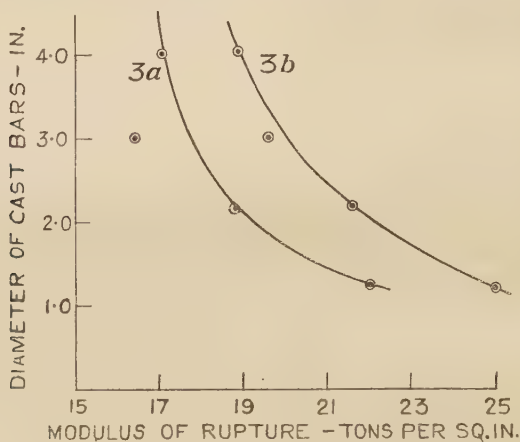
Fig. 3.—Rupture Moduli of Large Bars.

increases. What the bar gains in flexibility it loses in rupture strength.

The curves show a continuous diminution of strength as the diameter increases until a point is reached at which the rupture modulus becomes virtually constant, irrespective of the diameter. Fig. 3 shows tests on two series of bars for diameters greater than the standard 2·2-in. bar, the analyses for which are unknown. They represent common iron for engineering castings high in phosphorus. At the other extreme, as the section diminishes the metal changes and begins to mottle, ultimately becoming white. The strength which has hitherto steadily increased now begins to diminish owing to the brittleness of the free carbide, and there is a sharp discontinuity in the curve shown, for example, in Fig. 2a, while Fig. 4 shows three series from the author's results, the analyses being given in Table I.

The necessity for a number of points in the neighbourhood of the peak in order to determine the peak will be obvious. The peak represents the highest strength which can be obtained from a given diameter and for a given composition and set of melting conditions. The metal at the thickness represented by this point is much too sensitive to chilling to be used in ordinary foundry work, but the more nearly this peak can be reached the stronger will be the metal. Laboratory control, of course, enables
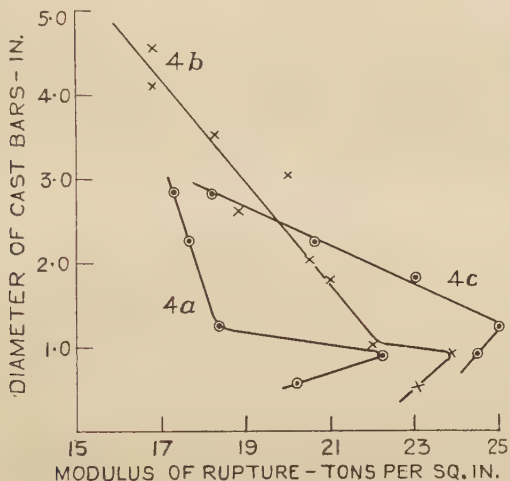
Fig. 4.—Rupture Moduli of Large Bars
showing Peak.

the point to be approached more closely than is otherwise possible. It will be seen that a given strength is obtained for two diameters, one on each side of the peak, but there would be a marked difference between the respective deflections.

Considerable care is required in moulding and casting sound thin test-bars, the minimum diameter called for in B.E.S.A. Specification 321, 1928, being 0·875 in. It will frequently be found that a low result on a thin bar is due to a defect in the bar, and not to the strength having passed its peak value. In order to ascertain whether the rectangular section would yield a similar characteristic, tests on rectangular bars were made from a series of some twenty casts, the bars for each cast being the ordinary 0·5-in. square bar at 12-in. centres, the Admiralty 1-in. square

1928—ii.   G

bar at 12-in. centres, and the B.E.S.A. 2 in. × 1 in. bar at 36-in. centres. Several of the curves, characteristic of the whole, are shown in Fig. 5, the areas of the bars being used as ordinates. The analyses appear in Table I.

It is found as a matter of common experience that square bars invariably give lower transverse results than round bars of similar size. It was uncertain whether this was a testing effect or a casting effect until some tests were made by Dr. A. L. Norbury
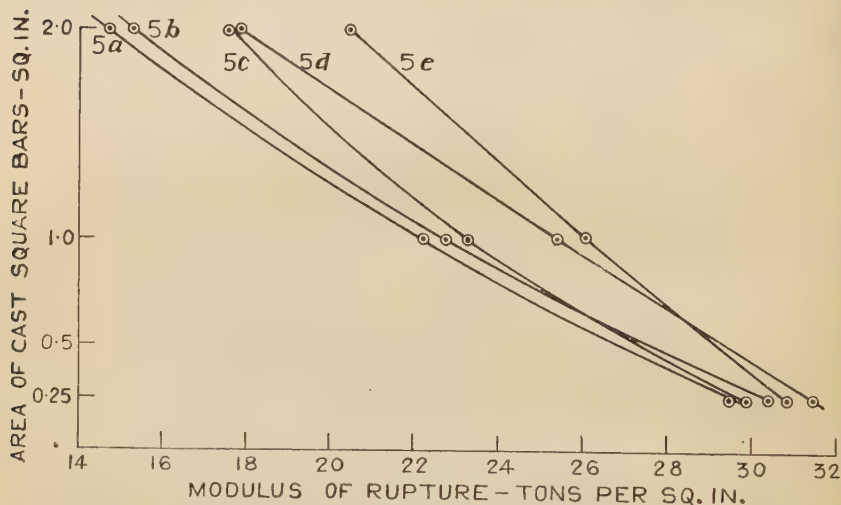
FIG. 5.—Rupture Moduli of Square Bars.

in the laboratories of the Cast Iron Research Association. A group of round bars was cast, some being skin-machined and others being machined square before testing. From the same metal a group of square bars was cast, some being skin-machined and others machined round before testing. The results showed clearly that the round bar is stronger than the square bar, even when prepared from a bar originally cast square, and that the square bar is weaker than the round bar, even when prepared from a bar originally cast round. The effect is therefore due, at least in part, to the distribution of stress across the bar during the test. The difference may amount to 10 per cent., or even over 20 per cent.

In square cast bars there is invariably a slight difference between adjacent sides. The influence of small dimensional changes makes it desirable that all square bars should be treated as rectangular, the longer side being the depth ; otherwise it is difficult to use recorded results without possibility of error.

The figures for breaking load for transverse bars of both grades
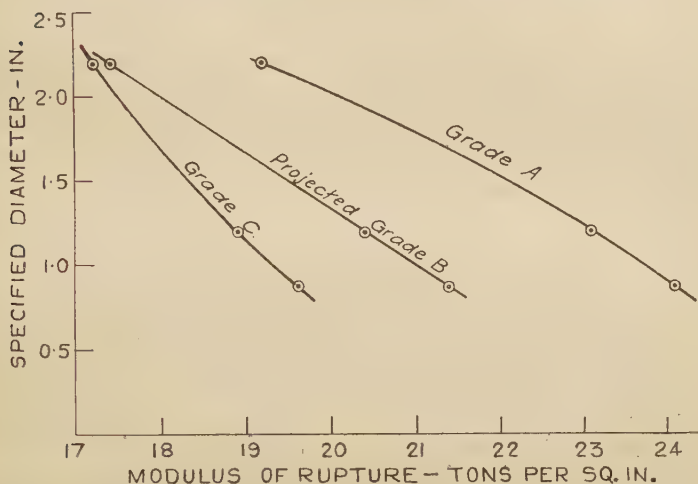
FIG. 6.—Rupture Moduli of Standard B.E.S.A. Bars.
Specification 321, 1928.

A and C of British Engineering Standards Specification 321, 1928,[1] were obtained in the main by direct experiment on large numbers of bars of all the standard sizes. The modulus of rupture determined from the specified breaking loads and diameter is shown plotted against diameter in Fig. 6, together with the curve for the grade B originally projected but as yet unspecified.

CURRENT METHODS OF TREATING TRANSVERSE RESULTS.

The difficulties introduced by current methods of treating the transverse test can be illustrated by recent contributions to the study of cast iron. It would appear in some cases that the

engineering formulæ utilised for converting the result on a cast size to the corresponding breaking load on a specified size have been treated as having universal validity. Many tests have been made, leading to the conclusion that the conversion formulæ do not hold for cast iron.

The formulæ, however, cannot be criticised as untrue or invalid because, by the circumstances of their development, they can only hold for conditions which are violated every time a transverse test is taken—that is, for perfectly elastic bars, or bars tested within their elastic limits and under such conditions that normal sections remain plane and the neutral axis passes through the centre of the section, that the elastic properties of the material remain the same in tension and in compression, and that stress is strictly proportional to strain.

The modulus of rupture on a cast-iron bar is not an absolute value even for bars of the same length and section. It is an index, however, of a particularly useful kind under standard testing conditions to the combined influences of constitution and rate of cooling on the mechanical strength——that is, of chemical composition, pouring temperature, mould temperature, and thickness.

A paper by Adamson and Bell [3] provides a particularly valuable collection of data in connection with the transverse test, since the actual bar dimensions and breaking loads are given for a series of bars of at least three diameters and for a wide range of compositions. The author has obtained characteristic curves from five of the compositions recorded, the actual rupture modulus being plotted against the diameter. The results are shown in Fig. 7, the corresponding analyses being given for convenience in Table I.

A paper by Rother and Mazurie [4] is also useful, inasmuch as it gives actual transverse results on bars of different compositions, shapes, and sizes up to 3 in. in diameter, all poured in the same foundry. Treated in the same manner, this paper yields definite conclusions which do much to dissipate the alleged mystery of cast iron and the capricious nature of its variations. Square and round bars in this series were cast from 1 in. to 3 in. across in five mixtures, four of which are now considered. Drawing the size-strength curves, the results are expressed in Fig. 8,
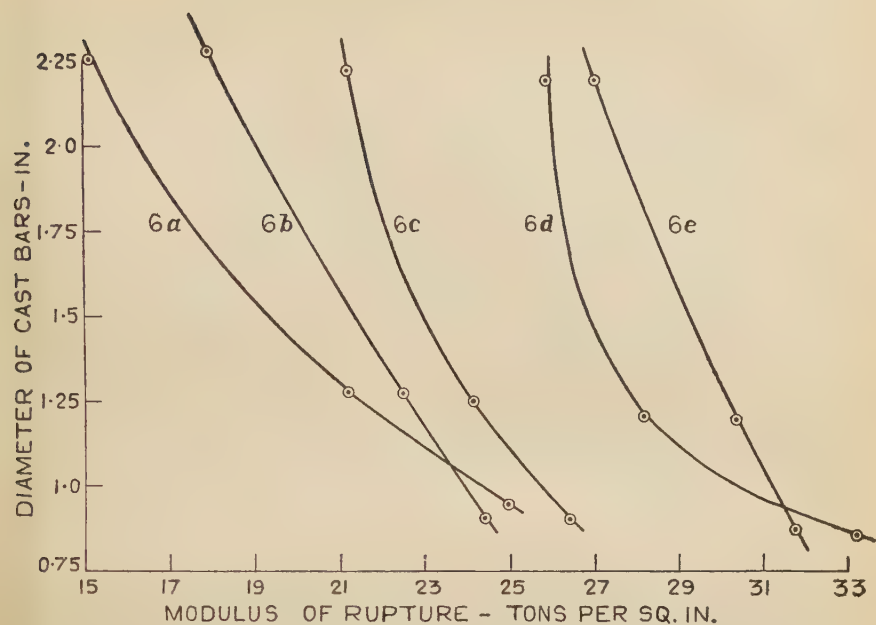
FIG. 7.—Size-Strength Curves from Data by Adamson and Bell.
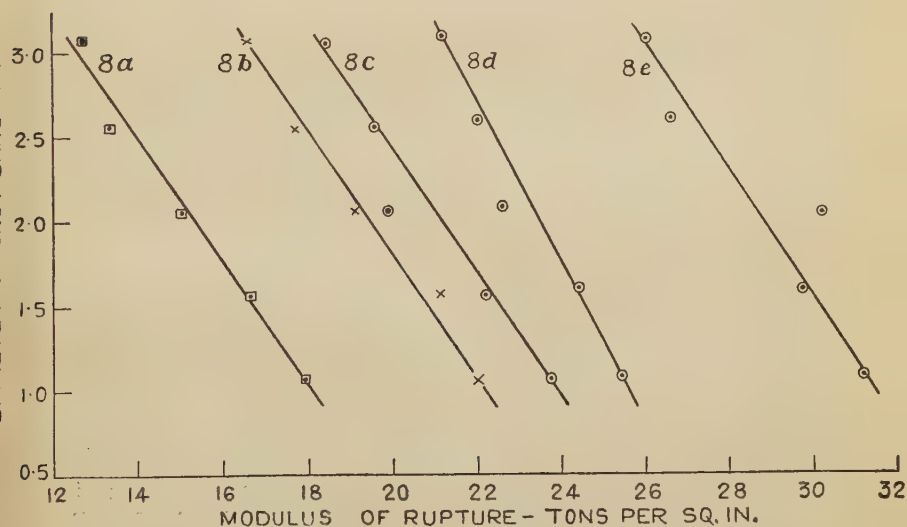
FIG. 8.—Size-Strength Curves from Data by Rother and Mazurie.

the analyses being given in Table I.   The curves yield the follow-
ing conclusions, which confirm the results given above :

1. Bars cast and tested square give lower specific transverse
   strengths than bars cast and tested round.   Thus, curves
   8a and 8b are for square and round bars for the same
   melt.   Other square bar curves are excluded.
2. A regular relationship exists between the rupture modulus
   and the diameter for bars of the same composition and
   method of casting.   The curves for the four melts of
   round bars shown, 8b, 8c, 8d, 8e, are practically straight
   and almost parallel.

A progressive relationship is also shown between strength and
composition (silicon content) for bars of the same diameter and
melting conditions.   This was foreshadowed in Fig. 1, and can
now be considered.

RELATIONSHIP BETWEEN STRENGTH AND COMPOSITION.

The aim of much recent research is to establish a relationship
between strength and composition of cast iron.   If these can be
shown to correlate even for a single set of melting conditions a
great step forward in foundry control becomes possible.   The
transverse test has been chosen for this correlation in the present
instance, not only because it is simple, cheap, and rapid, but
because, when expressed as rupture moduli, the results bear a
general relationship to other tests.   The experience of the British
Cast Iron Research Association is that the transverse strength of a
given iron is usually 1·8 to 2 times the tensile, which is usually
one-fifth to one-fourth of the compression strength.

The number of elements in cast iron makes such a relationship
particularly difficult to establish.   They may vary from cast to
cast, and it is unfortunately very difficult, under commercial
melting conditions, to maintain compositions constant except for
one deliberately varied element without having a wider range of
pig irons and a closer control of scrap than is usually necessary
in ordinary practice.   Strength, however, is predominantly in-
fluenced in a given section by the total carbon and silicon ;   in
these experiments the total carbon was not maintained suffi-
ciently constant to enable silicon alone to be used, and hence

" T.C. + Si " is used as an index to composition, although
" T.C. + $\frac{Si}{3}$ " might be a preferable combination.   The influence
of other variables of composition is for the time being ignored,
although the importance of phosphorus in this connection will
be obvious.   It may broadly be expected, however, that for
similar raw materials and melting conditions, differences in
strength in the same bar will be due to changes in composition ;
and for different melting conditions and similar compositions
strength differences will be an index to changes in melting con-
ditions.   This correlation of strength and thickness for different
sections is of particular importance to designers of engineering
castings, who at present have little or no reliable information on
this point, as it will lead to the more scientific disposition of
material in cast-iron structures, and prevent the indiscriminate
or promiscuous thickening of sections when an additional stress
has to be met.

Fig. 9 shows curves connecting the total carbon plus silicon
and the strength for bars of various thicknesses, derived from
Fig. 8.   They show a striking degree of consistency, indicating
that for a given melting régime there is little scatter, in spite of
the fact that two of the melts contained steel scrap.

An attempt to construct a similar curve from the results
published, for example, by Adamson and Bell,[3] or from the
results quoted by the present author, shows the degree of scatter
which would be expected from marked variations of composition
other than total carbon and silicon and from bars originating in
a number of foundries.   It is hoped at a later date to present
results from a systematic examination of a range of composi-
tions in British foundries.

Taking a mixture corresponding to curve 8c, Fig. 8, a bar
1 in. in diameter has a rupture strength of 23·9 tons per sq. in.,
and hence would carry 18·75 tons.   A bar 2 in. in diameter has
a rupture stress of 21·2 tons per sq. in., and hence would carry
66·6 tons.   Hence, when the area is quadrupled, the load-bearing
capacity is raised about 3·5 times.   An iron with a character-
istic similar to that shown in Fig. 1a under similar conditions has
its load-bearing capacity increased less than 3 times.

By the phrase " melting régime " is meant that particular

set of operating conditions which obtain at a given time in a particular foundry, or at least for one cupola of that foundry.   These conditions may vary slightly with alterations in raw materials such as coke, or with changes in personnel and supervision which involve changes in practice, but for practical purposes they may be taken as constant.   If for one such régime a series of bars be
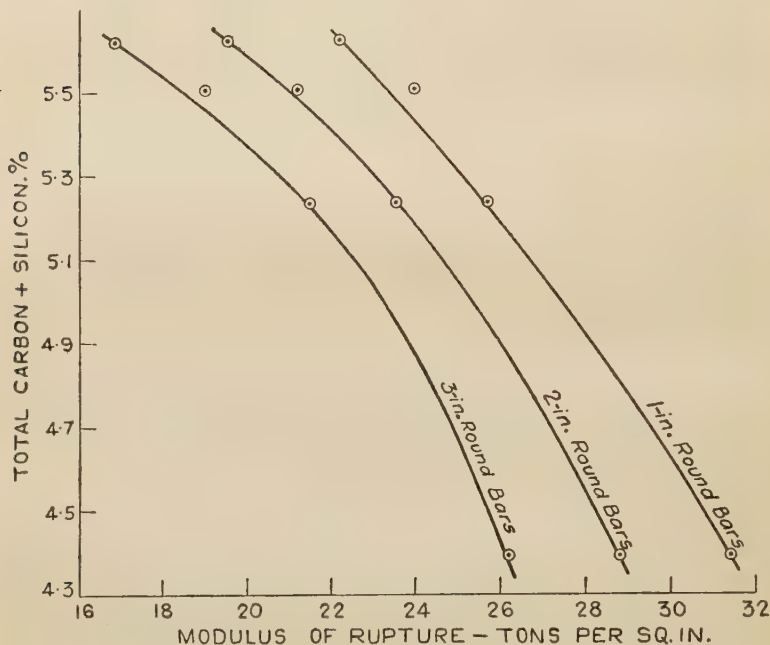
FIG. 9.—Composition-Strength Curves from Data by Rother and Mazurie.

cast in one usual mixture in a wide range of diameters, and if this be repeated for the whole of the mixtures normally employed, a diagram could be prepared similar to Fig. 9, which would give the transverse strength of a bar of any diameter within the range of compositions used.   Such a diagram would act as a base for the foundry.   It could also be used to determine compositions required to give a particular transverse strength, and hence a particular tensile strength.   With such a base it would then be possible systematically to ascertain the effect on strength of such operating changes as variations in cupola melting condi-

tions ; variations in charges without alteration of ultimate composition by the use of hot and cold blast irons, steel, and scrap ; variation in charges giving ranges of manganese, phosphorus, sulphur, and special elements ; and variations in moulding practice.

Finally, by direct experiment, the strength of standard bars could be compared with similar sections cut from actual castings.

Summary.

The number of variables encountered in foundry practice in the raw materials, in melting methods, and in moulding practice, combined with the range of tests by which strength is measured and the number of standard bars of any one test, have hitherto prevented the correlation of strength with size and of strength with composition, because the connection has been obscured.

It is suggested that by concentration on the new standard cylindrical transverse bar, and by casting bars of varied sizes and compositions, it becomes possible to chart relations between size and strength, and between composition and strength. It is shown that the transverse rupture modulus increases continuously as the test-bar diameter diminishes until the point is reached at which the metal ceases to be grey. The size-strength curve is a useful index to the behaviour of cast iron in thick sections, and the composition-strength curve deduced from a series of these promises to be of considerable assistance both to the designer of cast-iron structures and to the founder who has to realise the designer's ideas.

The transverse strength is closely related to tensile and compressive strengths, but this relationship is only shown if the transverse strength is expressed as rupture modulus, based on the area at fracture. It is hoped that the expression of transverse strengths as rupture moduli will become general.

The change of the rupture modulus with the diameter is so rapid that the use of conversion formulæ to bring a breaking load on a cast bar to a breaking load on a specified diameter may introduce serious errors. If the size-strength curve for a particular mixture and melting régime is known, deviations from the specified size can be corrected with much greater accuracy.

The author thanks the Council of the British Cast Iron Research Association for permission to publish this paper, and also thanks member firms and others, too numerous to mention individually, who have made the examination possible by providing test-bars.

REFERENCES.

(1) " British Standard Specification for General Grey Iron Castings, Grades A and C. No. 321, 1928." British Engineering Standards Association.
(2) G. HAILSTONE : " The Transverse Testing of Cast Iron," *Journal of the Iron and Steel Institute*, 1914, No. II. pp. 82–92.
(3) C. H. ADAMSON and G. S. BELL : " Transverse and Other Tests on Cast Iron Test-Bars," *Iron and Steel Institute, Carnegie Scholarship Memoirs*, 1927, vol. xvi. pp. 1–34.
(4) W. H. ROTHER and V. MAZURIE : " The Strength of Cast Iron in Relation to its Thickness," *Transactions of the American Foundrymen's Association*, 1926, vol. xxxiv. pp. 746–765.

DISCUSSION.[1]

Mr. J. S. G. PRIMROSE (Manchester) said he felt sure that there was much information in the paper which would be of great use to the engineer, when he came to make use of the results of test-bar figures in working out designs. The founder who had been accustomed to the test values obtained from the 2 in. × 1 in. or 1 in. square test-bar was astonished at the high values which the same class of iron gave with the new standard round bars. The effect had been in some cases to throw doubt on the accuracy of the testing machine used, but further check tests had only served to confirm the improvement effected in the test values. He was particularly interested in the section where the author was trying to establish a connection between strength and composition of cast irons, although it appeared to him that there was more likely to be merely a co-relation between strength and constitution. As illustrating that contention he referred to an interesting experiment recorded in the discussion of a paper by Adamson [2] showing how the strength of a set of test-bars, all cast from the same ladle of iron and having practically identical analyses, even to the percentage of combined carbon, varied considerably in the different sizes of square bar tested. The following results [3] were subsequently closely connected with the constitution, as shown by the microstructure, and in particular the size and distribution of the graphite and phosphide eutectic :

Side of Square. In.	Transverse Strength. Cwt. per sq. in.	Deflection on 1-ft. Span. In.	Brinell Hardness.
1	24·0	0·125	175
$\frac{3}{4}$	26·4	0·156	205
$\frac{1}{2}$	28·8	0·188	215
$\frac{1}{4}$	33·3	0·370	265

As the composition was practically unaltered, it would therefore appear more rational to seek a relationship between the constitution and the strength, rather than the composition. That was what might be expected from the practical point of view, and was largely a matter of the size and distribution of the graphite and phosphide.

Mr. F. S. WILKINSON (Dudley) said he would like to express his thanks to Mr. Pearce for his paper, which was one of considerable interest and importance to ironfounders.

It seemed to him that test-bars were not always a fair criterion of the strength of the casting, and points brought forward in the paper went to show some of the difficulties experienced in obtaining suitable

[1] At the Adjourned Meeting, Birmingham, Oct. 25, 1928.
[2] *Journal of the West of Scotland Iron and Steel Institute*, 1911, vol. xix. pp. 62–118.
[3] *Metal Industry*, 1926, vol. xxviii., Jan. 1, p. 15.

test-bars. In many instances the ironfounder was told that transverse and tensile tests would be required, and bars 2 in. × 1 in., 1 in. square, or $1\frac{1}{8}$ in. in diameter, were prepared, quite irrespective of the size or thickness of the casting, and one was left to wonder whether tests so obtained were worth while.

It was suggested in the paper that test-bars of varying sizes, depending on the size of the castings, should be specified; he felt that some definite standard should be employed for test-bars, and, in his opinion, the thickness of the castings should be an important factor in the matter. He would be glad to know Mr. Pearce's ideas on that matter.

Mr. E. ADAMSON (Sheffield) said that after the way in which the author had "hedged" his proposals with verbal qualifications, exceptions, &c., in introducing his paper, one wondered upon what specific grounds the suggestions in the paper had been put forward—and it certainly gave the impression that the author was not sure of himself. Another little matter should be mentioned to which the author made reference, namely, the "happy-go-lucky" method of making Diesel engine castings. It had been stated once before, in a paper given in London, that practically no one in this country could make Diesel engine castings; but from a personal knowledge of most of the large foundries in this country he (Mr. Adamson) could assure the author that in metallurgical matters there were no "happy-go-lucky" methods used in the principal foundries making Diesel engine castings. The mixtures were usually in the hands of trained men, and it was not true that they did not know their job.

Mr. Primrose had been good enough to refer to some test-bar experiments which he (Mr. Adamson) had carried out in 1910. From one ladle 1-in., $\frac{3}{4}$-in., $\frac{1}{2}$-in., and $\frac{1}{4}$-in. square bars were cast as quickly as possible, and afterwards all were tested on 12-in. centres. The 1-in. bars gave an average of 24 cwt., and the $\frac{1}{4}$-in. bars, using Unwin's conversion formula, gave 38 cwt. per sq. in. It was true, as Mr. Primrose pointed out, that the distribution of the phosphide in the $\frac{1}{4}$-in. bars was no doubt one of the causes of the increased strength, but it was also true that grain-size and size and distribution of graphite very largely contributed to the higher results. Mr. Primrose was keenly interested in the structure of those bars, and the series of micrographs which he kindly took in addition to his (Mr. Adamson's) own at 200 and 1500 diameters might well be considered by the author.

With those preliminary remarks he would pass on to a consideration of the paper.

Over twenty years ago it was the general opinion that the skin was the strongest part of a cast-iron test-bar, and that specimens gave higher results in both transverse and tensile tests than when machined. To test that the foundry of the Central Marine Engine

Works, West Hartlepool, was placed at his (Mr. Adamson's) disposal, and the results of that research, published in 1909,[1] showed that machined transverse bars gave tests 10 to 15 per cent. higher than those tested with the skin on as cast. Those results were confirmed in 1924 by G. S. Bell and C. H. Adamson,[2] who carried the matter a stage further by showing that, when transverse bars were machined down to 2 in. × 1 in. from varying oversizes, with $\frac{5}{32}$ in. machined off the tests fell. It was very satisfactory, therefore, to have Mr. Pearce confirm those 20-year-old results.

With the object of simplifying comparisons by a common factor for all sizes of transverse test-bars, in the same paper [3] he (Mr. Adamson) suggested that all transverse tests should be worked out to the moment of resistance, which was based on the section and length between supports. That test was well known to engineers, and the following was quoted from p. 217 of his paper :

" The tests show that whilst the transverse bars themselves may slightly vary, when worked out to this test (moment of resistance) based on the exact area, there is very little variation with the increasing silicon in one case and a fall in the strength in the other. On the other hand, in the case of the bars tested as cast and as machined, whilst the machined bars may show if anything a less favourable result, if the breaking weight is based on the exact area and worked out to the moment of resistance it gives upwards of 10 per cent. better breaking load and 40 per cent. better deflection."

Unwin's formula given in his paper was $\frac{1 \cdot 5WL}{bd^2}$, whilst that proposed by the author was $\frac{3WL}{2bd^2}$. It was evident, therefore, that with the same transverse breaking load the same final factor was obtained in each case. The modulus of rupture was the hypothetical skin stress at which a beam broke, and might be suitably used for small castings, such as piston rings, but the moment of resistance conveyed more to the engineering world generally.

The question of homogeneity of material did not appear to him to affect the matter. In view, however, of the recent research by Adamson and Bell referred to by the author, which disproved the reliability of the conversion formula when applied to cast iron, it became a question, would the use of such formulæ give a correct comparative moment of resistance, modulus of rupture, or any other similar factor ?

Further, it would appear to be the author's idea (p. 86) to standardise strength and " composition (silicon content)." As the same tests could be obtained with varying carbons, varying silicons, varying phosphorus, and varying manganese contents—how did he propose to do that ?

[1] *Journal of the Iron and Steel Institute*, 1909, No. II. p. 208.
[2] *Ibid.*, 1924, No. I. p. 347.
[3] *Ibid.*, 1909, No. II. p. 208.

A study of the detailed tables of the Adamson and Bell paper would probably save the author considerable loss of time, as it would amply illustrate the futility of trying to make tests depend upon chemical or " constructional " composition—the latter, being *calculated* from the former, whilst very interesting, was of no additional practical value, particularly as the size and distribution of the impurities could not be given. Incidentally, all his (Mr. Adamson's) tests, and also those of Adamson and Bell, were made on *commercial* cast iron, and casting conditions, including temperatures, &c., were as near constant as possible.

Several of the graphs given by the author in his paper gave definite indications of the difficulties to be met with in the task he proposed. In Fig. 4 graphs 4*b* and 4*c* were of practically the same " composition (silicon content) "—his own phrase on p. 86 ; yet the variations, particularly of the smaller size bars, were very great, which confirmed the findings of Adamson and Bell, and was also the general experience of practical men. Again, his graphs in Fig. 7 were at complete variance with what might have been expected if the " composition (silicon content) " had controlled the tests, for in that case 6*e* (Si 2·41 per cent.) should have given a lower test than 6*a* (Si 1·13 per cent.), because the harder the grey iron the stronger it usually was, yet 6*e* gave the highest tests of all in each size of test-bar. In fact, both the lowest silicon and the highest (Si 0·75 and 2·41 per cent.) gave higher tests than the intermediate silicons.

The author might, however, prefer the work of others. Hatfield [1] obtained widely different tests. Tables III. and IV. and curve III. were valuable references, all disproving silicon control. Earlier still, Guy R. Johnson [2] published what was perhaps the most exhaustive of the early researches on *commercial* cast iron, *i.e.* from blast-furnace products, and his Tables I. to XVII. showed that mechanical tests did not follow chemical composition, particularly if that were confined to variations of silicon, as suggested by the author.

In further confirmation, Fletcher,[3] a colleague of the author, drew some interesting conclusions. He stated : " The ratio of transverse rupture stress to ultimate tensile stress curve followed the silicon line closely on Fig. 1, *but in others the characteristics of the two curves were not so closely alike* "—in other words, they were dissimilar. Later Fletcher stated : " Fig. 5 has been prepared from a mass of test results, *to show how many different compositions (in respect to T.C. and silicon contents) may be used in obtaining iron of a given transverse rupture strength* "—another term used by Fletcher, possibly for the modulus of rupture. He (Mr. Adamson) wished to take this his first opportunity of thanking Mr. Fletcher for so fully confirming the attitude taken up by him for 20 years and supported by actual figures. In face of those

[1] *Journal of the Iron and Steel Institute*, 1906, No. II. p. 157.

[2] *Ibid.*, 1898, No. II. p. 200.

[3] *Proceedings of the Institute of British Foundrymen*, 1926–27, vol. xx. p. 188.

facts, how could the author hope to succeed where so many other equally eminent men had failed?

On p. 78 the author referred to change of strength with size of bar. It was now generally accepted that the smaller the grain-size on the same analysis the higher the test. It might also interest the author to know that it depended on the position of the test-bar on a big casting as to what test could be obtained as against a bar cast separately. That was forcibly brought to his (Mr. Adamson's) notice, probably 20 years ago, when he was consulted as to why a given mixture gave 11 tons when the test-bar was cast in a box and only $4\frac{1}{2}$ tons when cast on a casting. When told that the $4\frac{1}{2}$-ton bar had been cast on the boss of a propeller his answer had been, "What else did you expect?"— yet the bars were of the same "composition (silicon content)."

On p. 82, below Fig. 5, the author made some interesting statements, but omitted the facts; in the meantime, it was not proposed to dispute them, but they were accepted with reserve. For instance, were the comparative bars of the same size as originally cast or as tested? —for in the former case one or both of two factors had to be taken into account, namely, reliability of conversion formulæ, and grain-size, which had a very considerable influence on the strength of cast iron. In addition—and that would apply more to low-silicon irons—the crystallisation due to cooling would be different in the round and the square bars; hence if one were cut from the other the resulting tests might be expected to be different. Perhaps the author would give fuller details of his interesting data.

The question of how transverse test-bars should be tested (see p. 83) would perhaps interest the author—for there was a difference in the results obtained when the fin was in extension and when in compression. Table A of his (Mr. Adamson's) paper on the influence of silicon, phosphorus, manganese, and aluminium on chill would give him the information.[1]

On p. 84 reference was made to the mystery of cast iron; surely there was no mystery, for like all other metals it conformed to natural laws. That was his conclusion as a result of considerable practical investigation, but it had been necessary for him to go beyond chemistry to understand many of the problems which arose. Any suggested mystery was not cleared up by the very elementary expedient of varying the silicon; that had been tried over a great part of 40 years without success.

Many formulæ had been proposed from time to time, but not one of them could be generally applied. Latterly, " T.C. + Si " had been suggested, but the fact that the author suggested T.C. + $\frac{1}{3}$Si showed he was not satisfied. Therefore, any diagram as suggested by the author on p. 88 would be of little use in his endeavour to determine the composition—which on p. 86 he explained was silicon content— to give a particular transverse strength.

[1] *Journal of the Iron and Steel Institute*, 1906, No. I. p. 75. (See p. 91.)

In 1908 the first of what might be termed " current " new " T.C. + Si " formulæ was proposed, and there had been several since, but not one was in regular use to-day. Yet we still have new similar proposals. J. E. Hurst's paper on formulæ [1] would interest the author. In order to test the possibilities of the author's success in establishing a given composition for a given modulus of rupture test, Fig. 7 might be considered. In using those tests it must be understood that they were each an *average*, and so would show the author's proposals in a much more favourable light than if the individual minimum and maximum tests were graphed.

Curve.	Silicon. %	T.C. + Si. %	T.C. + $\frac{Si}{3}$. %	Modulus of Rupture.	
				Large Bars. Tons per sq. in.	Small Bars. Tons per sq. in.
6a	1·13	4·99	4·24	15	25
6b	1·93	5·61	4·32	18½	24½
6c	1·81	5·08	3·87	22	26½
6d	0·75	4·35	3·95	26	33½
6e	2·41	5·14	3·53	28	32

It could not be claimed from the above that " composition (silicon contents) " or either of the two formulæ quoted by the author controlled the tests, and the individual minimum and maximum tests on each size of bar would show still greater variations, as 13,014 min. and 15,880 max. (average on three bars, 13,971).

As if in confirmation of that, he would again refer to Fletcher's paper quoted above. He (Fletcher) stated : " In both sets of tests the important function of the combined silicon and carbon contents in regulating the structural strength and hardness is confirmed." Then later in the same paper, as if regretting what he had just stated, he said : " *The T.C. and silicon contents of a cast iron do not, therefore, indicate the strength of the iron*, unless the silicon influence, as shown by the ratio $\frac{Si}{T.C. + Si}$ "—another new formula—" is taken into consideration with that of the T.C." There were, however, at least two other influences overlooked by Fletcher—namely, grain-size and size of graphite—which were both very important factors in the metallurgy of cast iron, quite apart from the question whether the iron was hot- or cold-blast.

The whole trend of the author's paper was silicon control, which was surprising after Professor Turner's remarks in a discussion in Birmingham, at the Annual Meeting of the Institute of British Foundrymen, to which it would be well for the author to refer.

[1] Paper read before the Institute of British Foundrymen, 1928 ; *Foundry Trade Journal*, 1928, vol. xxxix., Oct. 18, pp. 281–282.

The author might not be aware that the question of silicon control was under discussion before the International Testing Association 20 years ago, and came to a head at the New York Congress in 1912. At that meeting he (Mr. Adamson) presented a number of tables disproving Kail's claim, and his (Mr. Adamson's) conclusions were accepted by the American representative, who had been the chief advocate in urging the silicon grading of pig iron. Since then there had been many investigations published in the American technical press, all showing that other properties in addition to chemical composition must be considered in connection with cast iron. Dr. Moldenke was also now an advocate of the value of fracture, no doubt as a result of convincing evidence given to him on his visit to Sheffield in September 1923. That evidence was also available to the author.

As a result of a life-long connection with cast iron for every class of casting, it was his invariable experience that to obtain mechanical tests within a given " chemical " specification it was necessary to select the materials for their *physical* properties. Having done so it might then be possible to work to chemical composition within broad limits, but to say that was working to analysis would be misleading, for, as a matter of fact, the same mechanical tests were regularly being obtained *and could be repeated* on widely different chemical compositions. That was amply confirmed in papers published by an official of the British Cast Iron Research Association confirming older workers.

The function of the chemist in the iron foundry was becoming an important one, but it was not being helped, nor was he being assisted by endeavours to try to establish chemical formulæ to control mechanical tests ; it was, in fact, doing the chemist a serious disservice. During the early part of the last quarter of a century, when comparatively little was known about the technical side of cast iron, many worthy and very keen young chemists lost their reputations by endeavouring to control mixtures in the iron foundry entirely by chemical composition, which generally amounted to variations of silicon. It had taken nearly 20 years of discussion to show that silicon did not control mechanical tests, and it would therefore be much more helpful, particularly to the younger metallurgist, if that position were fully accepted, particularly as the eminent authority, whose work 40 years ago was responsible for the theory, had officially dissociated himself from silicon control.

It would certainly be of very great value indeed to the engineer *if* he could be given a formula upon which he could absolutely rely to enable him to make engineering calculations. Had the author been longer in the iron foundry world he would have known that he was not the first to wish to help the engineer, but to suggest a formula which ignored sulphur, phosphorus, manganese, the physical properties of cast iron disclosed by fracture, the size and distribution of the impurities, &c., and by reason of this having to " hedge " a formula with numerous safeguards of which the engineer knew nothing whatever,

was only to put him in a false position. Had he (Mr. Adamson) been able to suggest any method of helping the author the offer would have been made, but in his opinion present knowledge was not sufficiently advanced to warrant any suggested formula. Much more work would need to be done before any definite proposal could with wisdom and advantage be put forward.

Mr. V. E. GREEN (Birmingham) said he had read Mr. Pearce's paper with great interest. In the discussion some reference was made to the design of cast-iron bed-plates for large engines ; his experience had been that bed-plates were not designed from the point of view of the strength of the materials, and a great deal was left to the pattern shop and foundry people to produce the most satisfactory article. The designer had hitherto lacked the information put forward in Mr. Pearce's paper, and such information should enable the engineer-designer to calculate better the strengths of large bed-plate castings.

The time had certainly come when the size of the test-bar should have a definite relation to the general measurements of the casting. So far as the testing of cast-iron bars under transverse conditions was concerned, the round bar was convenient in many ways. It could be more easily skin-machined, and even if not machined it accommodated itself more easily to the testing machine. With some rectangular test-bars the faces were in winding, and when the bar was transversely loaded complicated side bending actions were set up.

He believed that the paper summed up the whole subject very well, and should be a great help to the designer. Research work in industry as a whole should be directed towards helping the designer, so as to make progress on past designs.

Dr. A. B. EVEREST (Birmingham) expressed his thanks to Mr. Pearce for his very interesting paper, and especially for emphasising the fallacy in correcting the moduli obtained from over- or under-sized bars by means of the simple ratio of the diameters of the bar under test and of the standard bar. The question of that correction frequently occurred in general research work on cast iron, and often the variation in size of test-bars cast was very great as compared with the standard bar ; thus considerable errors, as Mr. Pearce had pointed out, were thereby liable to arise.

On p. 82 Mr. Pearce stated that it was found as a matter of common experience that square bars invariably gave lower transverse results than round bars of similar size, and he (Dr. Everest) would rather like to give that statement further consideration. If the modulus of rupture were an absolute strength figure for the material under test, then it should be independent of the method of test ; the variation between results obtained on round and square bars clearly indicated that there was something wrong. He would venture to suggest that the error occurred in the formulæ used for calculating the modulus,

rather than in the actual method of testing; and the formula which might be at fault was that used for the round rather than for the square bar. In that formula it was assumed that the neutral axis in the test-bar section during test was situated on a plane located at half the depth of the test-bar; was that assumption justified? Again, in Fig. 5 was it fair to plot the points for the bars of 2 sq. in. area where they were shown, when, as Mr. Pearce had pointed out, those points were obtained from bars 2 in. × 1 in. tested on edge, and the other points were obtained on bars actually square in section? He would suggest that the positions of those points, and consequently the shapes of the curves, would be very different if the figures were obtained from square section bars of 2 sq. in. area, or, again, if they were obtained from 2 in. × 1 in. bars tested on the flat.

Mr. W. A. BENTON (Birmingham) said it had seemed to him for a long time past that steps ought to be taken to obviate the great divergence in results when testing the same quality of iron due to the use of standard test-bars under the widely differing conditions obtaining in practice. If a casting were very thin and an inspector insisted upon a 2 in. × 1 in. bar, it was certain that the bar would give a much lower test figure than the casting the strength of which it was intended to check. Again, the influence of large slowly cooling masses of metal in the vicinity of a test-bar unquestionably detracted from the strength of the latter. Obviously some relationship ought to be established between the size of the test-bars and the castings with which they were intended to be used. He did not, however, see his way to make any suggestion.

As regards the place of the chemist in iron foundry practice, he could only exercise one kind of control. The making of a suitable iron for any given purpose depended upon a large number of conditions, such as the magnitude of the masses under treatment, temperatures, quantity and temperature of blast, &c. The chemical composition of the materials and of the resulting iron were important, but not exclusively important, factors. When a metallurgist had made his iron the chemist could help him to control one set of factors that was concerned in the maintenance of the desired quality, but nothing the chemist could do would be of service unless the other conditions were also maintained.

The CHAIRMAN (Mr. GEORGE HATTON, C.B.E., Member of Council) said he would like to ask the author if in studying the control of silicon he took into consideration the percentage of sulphur in the iron, bearing in mind the fact that sulphur had a counteracting effect to silicon in the ratio of about one part of sulphur to five parts of silicon, or vice versa. It seemed a factor to be considered.

CORRESPONDENCE.

Mr. J. W. BOLTON (Cincinnati, Ohio) wrote: In referring to a paper by Rother and Mazurie, the author states (p. 84): " This paper yields definite conclusions which do much to dissipate the alleged mystery of cast iron and the capricious nature of its variations." Further (p. 86), he says: " The aim of much recent research is to establish a relationship between strength and composition of cast iron. If these can be shown to correlate even for a single set of melting conditions a great step forward in foundry control becomes possible." Thus, the author has unconsciously set up the standards by which his own paper may be judged, and the remarks he made relative to the paper of Rother and Mazurie may well be applied to his own.

That skin-machined bars are advisable, particularly in research work, is true. It is well known that even tiny flaws on the tensile side of the transverse bar have a marked effect on the ultimate strength. It is doubtful whether this effect of skin machining is noticeable in the lower ranges of the stress-strain diagram—*i.e.* would there be any material change indicated in the modulus of elasticity within the usefully stress-resistant ranges ?

It would seem that " out-of-round " bars are a more serious problem than are over-size or under-size bars, since these latter can be interpreted mathematically with at least a fair degree of accuracy for small dimensional changes. It will be found that the error involved in such calculations is much less in the case of some irons than in others—some irons changing much more slowly in strength as the dimensions of the bar are varied ; also, as noted by the author, the error is much less in some parts of the stress/casting-size curve than in others.

On p. 80 the author states: " It has also been found that in bars of the same material cast at the same time, the modulus of rupture increases and the deflection diminishes as the span diminishes." No explanation is given. Leaving aside the consideration of deflection, whose diminution is largely explicable on purely mathematical grounds, it is at once apparent that some if not all of the difference in breaking stress is due to the different cooling rate of the longer bar. This factor, cooling rate, receives too little consideration by the author, the inference from the paper being that it is the bar diameter rather than the more fundamental $\frac{\text{volume}}{\text{surface area}}$ relationship which is the determining factor. (Some may claim, for precision's sake, that the weight of bar suspended between the supports is greater the larger the bar. However, this is well within the limits of experimental error.)

The danger attendant on the use of the sum Si + C for a composition index is clearly shown by the writer.[1]   The use of $C + \dfrac{Si}{3}$ is preferable, although the writer prefers $C + 0\cdot3$ Si, since this indicates roughly the position of the alloy in the iron-carbon diagram.

With all due respects to the author's otherwise excellent paper, there is so great an insufficiency of pertinent information that it is difficult, if not impossible, to make intelligent comparisons with other actual test results.   For example, when indicating moduli of rupture obtained by various investigators, nothing is given about span, nor are any test results given in tabular form, capable of quick and accurate comparisons.

Dr. J. W. DONALDSON (Greenock) wrote :   The author's paper forms an important contribution to the work done during recent years on the testing of cast iron, and shows conclusively that the results obtained by the transverse test may vary considerably over a wide range, according to foundry treatment, composition, and size of test-bar.   The method of expressing the transverse test as the actual breaking load, irrespective of the actual section, is to be condemned. If a 1 sq. in. bar be considered, very few are cast accurately to size, and it is not generally realised that $\frac{1}{16}$ in. over or under size gives an error in the area, using the formula $D^2 \times B$, of approximately $\pm$ 18 per cent.   In the round bar, allowing a casting tolerance of $\pm 0\cdot1$ in. on a $1\cdot2$-in. bar, points C and D (Fig. 1) show a range of $1\cdot8$ tons per sq. in., that is, $8\cdot5$ per cent.   That being the case, one feels that more accurate results would be obtained by casting a specified amount over size and then skin-machining to a definite dimension.

It is pointed out that square bars invariably give lower transverse results than round bars of similar size.   This might be expected, as the bending formulæ used for obtaining the strength only hold good up to the elastic limit of the material.   Stresses are at a maximum in the grains most remote from the neutral axis.   In bars of square or rectangular cross-section, the elastic limit is exceeded in the full width of the outer layers, whereas in bars of circular cross-section only a very narrow layer reaches the elastic limit at first, and the higher rupture strength obtained in round bars may be attributed to the slower rate at which part of the section attains and passes its elastic limit.

Expressing the transverse strength as rupture modulus and having a series of " composition-strength " curves derived from bars of various sizes will be of considerable assistance to engineers and designers. The term " modulus," however, is to be criticised.   The various moduli in use are ratios involving stress and strain, and have an

[1] *Transactions of the American Foundrymen's Association*, 1928, vol. xxxvi. pp. 507–512, Figs. 17–21.

interpretation quite different from that intended by the author. The term " rupture strength " is more correct, and would not be so misleading to both designers and founders.

Mr. J. Shaw (Southsea) wrote : The thanks of all foundrymen are due to Mr. Pearce for the clear and logical reasons which he gives for the issue of Specification No. 321, 1928. He shows clearly the need for using several sizes of test-bar to represent the cooling effect of different thicknesses of cast iron, and the weakness of any one size of bar to represent even the quality of the metal in the ladle, if that metal is suitable for a casting with much thicker or thinner metal than the test-bar. It gives a logical answer, why, with increasing thickness of either casting or bar, the test-load per square inch needs to be reduced. The curves given in Fig. 1 supply a clear reason why the breaking loads were fixed so low (although higher than the superseded one). Several members advocated more than three sizes of test-bars to meet this, but it was felt there must be a limit for practical reasons. There would be little difficulty in giving higher tests if the bar and section of casting were the same, but now the 1·2-in. diam. bar is used for all castings from $\frac{7}{8}$ in. to $1\frac{7}{8}$ in. thick.

After proving by means of curves that the modulus figure for a 2·2-in. diam. bar must have a lower breaking load per square inch than that of the 1·2-in. diam. bar, it is difficult to understand Mr. Pearce's constant use of the modulus. This was definitely turned down in Committee, because, when dealing with cast iron, the modulus figure for one size of bar will not hold good for another. Graphs and formulæ seem to be necessary to a scientific mind, whether adaptable or not. The T.C. + Si formula is a case in point. Hurst [1] recently showed the futility of this, which only takes account of two elements. Take the results given in Turner and Hague's paper [2] ; the addition of 0·5 per cent. of manganese to a cast iron having a given T.C. + Si content caused the combined carbon to drop from 0·84 per cent. to 0·22 per cent. Or, again, take two examples from a recent German paper [3] :

T.C. + Si. %	T.C. %	C.C. %	Si. %	Mn. %	P. %	S. %	Transverse Strength. Tons per sq. in.	Tensile Strength. Tons per sq. in.
5·74	2·35	0·62	3·39	0·60	0·023	0·023	40·5	27·4
5·41	3·59	0·72	1·82	0·69	0·490	0·116	20·9	9·3

With the higher T.C. + Si the strengths are twice and three times as high respectively. No further comment is needed.

[1] J. E. Hurst, " Grey Cast Iron," *Paper read before the Institute of British Foundrymen*, 1928 ; *Foundry Trade Journal*, 1928, vol. xxxix., Oct. 18, pp. 281–282.
[2] T. Turner and A. Hague, " The Influence of Silicon on Pure Cast Iron," *Journal of the Iron and Steel Institute*, 1910, No. II. pp. 72–93 (see p. 90).
[3] P. Bardenheuer and K. L. Zeyen, " Contribution to the Knowledge of Graphite in Grey Cast Iron and its Influence on the Strength," *Die Giesserei*, 1928, vol. xv., April 20, pp. 354–365 ; April 27, pp. 385–397 ; May 4, pp. 411–420. (*See* melts 109 and 170, Tables VIII. and XII.)

The same applies to any effort to correlate composition to strength. The author works backwards—that is, he makes his deductions from a casting already made and one with a definite cooling rate. Any table he compiles should enable a composition to be fixed before casting. There are a number of questions affecting this agitating the foundry world at the present time : The effect of any free graphite in the molten metal due to the rapid melting of cupola metal ; this is supported by such a sound carbide man as Portevin. The question of highly superheating the metal to destroy any free graphite, and also its effect in considerably lowering the freezing point and causing finer graphite. The effect of using synthetic material on the graphite, and, perhaps of most importance, the type of casting itself ; in a recent case, due to the heat-retaining qualities of a jacket core, the combined carbon was only 0·05 per cent. instead of 0·6 per cent., while the strength was less than 8 tons. I know Mr. Pearce covers himself on these points, but a table correlating composition to strength and thickness coming from such a source would be a snare to many. The object is good, but the time and our knowledge of cast iron are not yet ripe.

The AUTHOR, in reply to Mr. Primrose, agreed that there was likely to be a relationship between strength and constitution rather than between strength and composition, for mechanical strength was determined primarily by structure, which should be expressed constitutionally rather than by ultimate chemical analysis. It was unfortunate that Mr. Primrose and Mr. Adamson were not in agreement on that point, arising out of a piece of work in which they were mutually concerned, although the bars were, contrary to Mr. Adamson's suggestion, apparently not cast by him but by Mr. R. M. Campbell. The author agreed with Mr. Primrose, but, unfortunately, owing in part to lack of data respecting certain fundamental constants of such constituents of cast iron as pearlite and cementite, and in part to gaps in our knowledge of the mode of solidification of cast iron in relation to composition and rate of cooling, it was not yet possible either to determine or to predetermine constitution from composition with accuracy. One was thus at present forced back on composition, which, of course, could only give a first approximation to the truth.

In reply to the important point raised by Mr. Wilkinson, metallurgists fully recognised the difficulty of interpreting test results for castings of varying sizes by means of the same size of test-bar. In view of the last suggestion made in his contribution, Mr. Wilkinson would be interested to know that the British Engineering Standards Association's general specification for grey iron castings, in addition to standardising the round bar cast away from the casting, made provision for three sizes of test-bar according to the section of the casting represented. Thus the 0·875-in. diam. bar represented castings having a main cross-sectional thickness of 0·75 in. ; the 2·2-in. diam. bar

represented castings having a main cross-sectional thickness of over
2 in., while the intermediate 1·2-in. bar represented castings having
sectional thicknesses between 0·75 in. and 2 in.   That correlation
between size of bar and thickness of casting marked a great step forward,
and the specification, which had the author's full support, would, he
thought, meet the suggestions made by Mr. Wilkinson.   Ultimately
the number of bars might be increased and provision made for bars
representing very thin and very thick castings.

In replying to Mr. Adamson's lengthy contribution, the author
would endeavour to be as brief as possible by sedulously avoiding the
making of mere debating points.   The qualifications introduced into
the paper were clearly defined, and were introduced solely to emphasise
the fact that the curves at this stage had no general application, but
must be ascertained by each foundry for its own product.   At present
not enough was known about cast iron to enable the multitude of
variations in raw material, in mixtures, in melting practice or in mould-
ing practice to be taken fully into account.   In presenting the paper
the author had in view three main principles : First, the variety of
transverse test-bars at present in use and the differences introduced
by their modes of attachment to the casting made it impossible to arrive
at a rational relationship between tensile and transverse strengths.
He therefore advocated the use of B.E.S.A. specification No. 321, which
standardised the bar and method of casting.   Secondly, the expression
of transverse breaking loads without reference to the actual section of
the bar resulted in serious errors, while the practice of converting the
breaking load on a cast size to that on a specified size by the method
of proportion was erroneous, because the mathematical procedure
involved ignored the difference in rate of cooling between the two sizes.
That made a smaller bar specifically stronger and a larger bar specifi-
cally weaker than a nominal size.   Thirdly, the author desired to illus-
trate the continuous nature of the variations of the strength of cast iron
with section and, within certain limits referred to below, with composition.

The author's reference to the empirical design of iron castings, which
did not extend to foundry practice, appeared to have been misunder-
stood by Mr. Adamson.   His (Mr. Pearce's) observations were amply
confirmed by the engineers who spoke in the discussion.

With reference to his necessarily compressed references to the
influence of machining, the author disclaimed any intention of confirm-
ing or refuting Mr. Adamson's twenty-year-old tests, but merely referred
in passing to common experience in testing machined and other test-
bars, and offered a reason why, although the skin was the strongest
part of a test-bar, skin machining often improved the strength.   The
effect of machining which, according to Mr. Adamson, was obtained
by Bell and Adamson in 1924, was, in point of fact, amply demon-
strated in America as far back as 1900.[1]   The author accepted

[1] *Journal of the American Foundrymen's Association*, 1900–1, vol. ix., and
1901–2, vol. x.

Mr. Adamson's contention that Bell and Adamson's paper disproved the reliability of conversion formulæ applied to cast iron. His point was that a consideration of the conditions under which the formulæ were derived and remained valid showed that any such attempt at conversion was fundamentally erroneous.

The author was unable to follow the distinction drawn by Mr. Adamson between moment of resistance and modulus of rupture, since the latter was merely the former divided by a constant, the section modulus. The author suggested that, in view of the idea of constancy associated with the term "modulus," the phrase "modulus of rupture" for the transverse strength of cast iron at fracture might be replaced by the phrase "transverse rupture stress," as, indeed, Dr. Donaldson virtually suggested.

Mr. Adamson was in error in assuming that the author was unfamiliar with previous contributions to the subject. The fact that irons of somewhat similar silicon content gave differing size-strength curves did not affect the utility of the latter, for, as indicated above, the curve was true for a particular composition cast in a particular foundry. The testimony paid by other speakers in the discussion to the value of the method of treatment sufficed to show that it was likely to prove useful. The curve marked 6e in Fig. 7 gave high strength figures on account of the unusually low total carbon. The significant feature was that it should be similar in general type to other curves for other mixtures showing lower strengths.

The most controversial point in the paper was the use of the sum "total carbon plus silicon" as a criterion of composition. The choice of that was deliberate. Its shortcomings were obvious enough. It ruled out of account the influence of manganese, sulphur, phosphorus, alloy additions, as well as casting temperature and melting temperature. It assumed that irons of similar graphite and phosphide content, but differently distributed, had the same strength, which was known to be erroneous. It assumed that a slight diminution of one element could be balanced by a slight increase of the other, which was also known to be erroneous. A two-dimensional diagram, however, imposed limitations, and some variables had to be omitted. Furthermore, on the whole, in the engineering irons mainly dealt with by the author, particularly those of predominantly pearlitic character, the sum T.C. + Si did very broadly determine the strength, and the diagrams did not pretend to be more accurate than that sum dictated. Mr. Adamson made considerable use of the fact that irons of widely differing silicon contents had approximately the same combined carbon content. In the author's experience, however, the mechanical strength of cast iron was not governed by combined carbon so completely as Mr. Adamson appeared to believe, and mechanical strengths did not follow combined carbon contents very closely. Changes in combined carbon took place in steps, changes in strength were gradual, and that afforded more ground for the use of the sum proposed than Mr. Adamson was prepared

at present to believe.   The author was familiar with the tests covered in
the paper by Fletcher to which Mr. Adamson referred.   His (Fletcher's)
conclusions remained broadly true, that in a series of experimental
irons made up in several types of furnaces and foundries for the purpose
of investigating the properties of grey iron as a whole, and including
synthetic and other mixtures, there was no direct connection between
mechanical strength and composition.   Some work of the British Cast
Iron Research Association which would be made public during the next
few years would throw a great deal of light on that point.   For ordinary
engineering irons, however, made in the ordinary way from ordinary
pig and scrap, the connection between total carbon plus silicon and
strength was sufficiently pronounced to warrant its use.   The *prima
facie* evidence given by the curves themselves was completely ignored
by Mr. Adamson ; yet the curves shown were not a selection.   To take
a set of miscellaneous results from different foundries and to compare
rupture stress with composition, as Mr. Adamson had done in his table,
was completely to misconceive the aim of the paper.

The author thanked Mr. Green for his remarks, which admirably
stated, from the engineer's point of view, the reasons why the paper
had been prepared, and his advocacy of the round bar from the point of
view of testing procedure was valuable.   The tests made for the paper
were carried out on the excellent equipment housed and used in the
laboratory attached to the Birmingham Corporation Gas Department.
The tests on large bars were quite outside the range of an ordinary
small machine, and the author would take the opportunity of acknow-
ledging the help he had received in that connection from Dr. Walter
and Mr. Green.

In reply to Dr. Everest, the author preferred to regard the beam
formulæ as accurate, for they were based on strict theoretical principles,
and to regard the error as arising in the test.   The conditions for which
the formulæ remained valid were violated by a test which loaded the
bar beyond the elastic limit.   It was true that the rupture modulus
for cast iron was affected by bar dimensions and span, but if they were
standardised, strictly comparable results were obtained.   Strictly
speaking, the shape of the bar was taken into account by the section
modulus Z in the formula, and hence in the bend test homogeneous
and ductile materials did not show the difference between round and
square sections.   Since the compression strength of cast iron was
about four times the tensile strength, the neutral axis would be dis-
placed towards the compression edge of the bar ; consequently what
was true of a material of similar tensile and compressive strengths
could not be true for cast iron.   The author thought that round and
square bars not only had section moduli which differed from the
theoretical, but that they bore a different ratio to the theoretical in
each case.   That explained the differing strengths of round and square
bars of the same material.   Dr. Everest's point that the 2-in. × 1-in.
bar might not behave like a square bar of like area was a fair criticism,

and the author would take an opportunity of seeing how the square bar behaved in comparison with the rectangular bar.

The very interesting comments of Mr. Benton had been covered in part in the reply to Mr. Wilkinson. The author fully agreed that the chemist, as chemist, could not be an autocrat in the foundry.

In reply to Mr. Hatton, the author had not specifically included sulphur, because the effect of sulphur depended so much on the amount of manganese present, and the tendency in modern engineering irons was to increase the manganese percentage. In any case, the precise effect was indeterminate, owing to the reversible nature of the manganese-sulphur reaction, and at the present stage it had been necessary to rule out the influence of sulphur. The British Cast Iron Research Association was shortly publishing a paper on the influence of manganese in relation to sulphur, after which the effect of the residual sulphur on silicon would be clearer.

The author was indebted to Mr. Bolton for his comments, for he had touched on one of the few difficulties connected with the round bar in referring to " out-of-round " bars. Careful moulding was very necessary. The author agreed that machined and unmachined bars were unlikely to show a marked difference in the elastic modulus. He had not given figures in detail showing that the rupture modulus increased and the deflection diminished as the span diminished, partly on account of space and partly because his conclusions broadly confirmed those of Mathews [1]; he agreed that the extra length of the long bar was in part responsible, as suggested by Mr. Bolton. The author had not found the weight, even of the heaviest bars, a serious factor in that direction. He was familiar with the relationship between volume and surface area as a measure of cooling rate, for its reciprocal was advocated by Fletcher as a cooling ratio in 1918,[2] and it had, in fact, been used by Keep as early as 1895.[3] Ignoring the ends as having little influence in a bar of more than 10 diam. long, the ratio mentioned by Mr. Bolton was $\frac{1}{4}$ of the diameter, which was clearly proportional to the diameter used by the author.

Since each curve showed clearly the points on which it was based, the author did not burden the paper with tables. In early tests he used spans recommended in the B.E.S.A. specification, but in view of the slight difference in rupture modulus between 18-in. and 12-in. spans, he adopted 18 in. as a uniform figure, and that applied to Figs. 1 to 4 inclusive. Later, in order to get a reasonable deflection on heavier bars, a span of 21 in. was adopted for 24-in. bars, and that was at present the author's standard.

Dr. Donaldson had very clearly grasped the errors involved in

[1] C. D. Mathews, *Proceedings of the American Society for Testing Materials*, 1910, vol. x. pp. 299–305.
[2] J. E. Fletcher, *Journal of the Iron and Steel Institute*, 1918, No. II. pp. 231–271.
[3] W. J. Keep, *Transactions of the American Society of Mechanical Engineers*, 1895, vol. xvi. pp. 542–568.

conventional cast iron testing, and the suggestion for oversize casting and skin-machining was a good one.   The author thought it preferable to specify the amount to be machined off rather than the finished size. In either case, however, a larger margin was required on a large bar. For small bars $\frac{1}{16}$ in. should suffice, and for intermediate sizes $\frac{1}{10}$ in. The author believed that Dr. Donaldson's explanation of the difference between the round and the square bar had much to commend it.   If the stress distribution were visualised for each case, Dr. Donaldson's point was at once appreciated.

In reply to Mr. Shaw, who queried the use of the modulus, it would have been equally as satisfactory for the purpose of the author's curves to use the breaking load as to use the transverse rupture stress. In ordinary testing, however, the difficulty was that it was impossible to cast a specified size accurately, and when the load for an oversize or undersize bar was obtained the conversion method did not give accurate results.   There was thus no alternative but to give the rupture stress on the actual section at fracture.   The use of that could only be avoided when the size-strength curve was known, as was the case for the B.E.S.A. specification.   The question of total carbon plus silicon has been dealt with in reply to Mr. Adamson.

The experimental alloys of the kind quoted by Mr. Shaw, made in the crucible, showed differences which were in process of being understood and explained, but they were not met to anything like the same degree among ordinary commercial irons.   The author urged that the paper be taken as an illustration of a method of treatment rather than as giving final results, and that each foundry should work out its own curves for its own mixtures and melting conditions.   The author did not attempt to correlate composition and strength, but to indicate how each foundry might establish its own correlations pending further developments in the subject.

THE PHENOMENA OF CORROSION OF IRON AND STEEL.[1]

By A. HERRERO and M. de ZUBIRIA (Bilbao).

When one observes the growing interest with which manufacturers and consumers of metallurgical products study every process that may lead to an improvement in manufacture and to a fuller application of the products, when one notes the multiplication of chemical laboratories and mechanical tests, and when it is considered that metallography has become the guiding science in metallurgical industries, one notable fact stands out pre-eminently —namely, that although all methods of analysis and for the study of the properties of ferrous products have become standardised, so that it is possible to manufacture new alloys to meet the manifold and various requirements of industry, of which the special tool steels are a notable example, and though the causes of failure of any piece in service can be determined or a fault detected with certainty—in a word, though it would appear that the fundamental problems of metallurgy have been mastered—the most fundamental problem of all still lacks adequate elucidation. Briefly, that problem consists in the study of the influence of the atmosphere in causing deterioration of metallurgical products, or, in short, of the phenomenon of corrosion. For in truth wherever circumstances compel the use of metals in the open air they must of necessity be subject to atmospheric influence.

That the question is of fundamental importance is obvious when one considers not only the enormous tonnage of material which on account of corrosion is annually discarded as scrap, but that 4 or 5 tons of coal, or its equivalent, are consumed per ton of steel, from the getting of the ore to the finishing of the product. It is clear, therefore, that by allowing this to continue instead of attacking the evil at its source, we are depleting our reserves of fuel for which no substitute has yet been found.

Assuming, as a starting-point for subsequent calculations, that the world's annual production of steel is 100 million tons, and that the average life of iron and steel products is 30 years, it means that at the end of that period this enormous production will have been converted into scrap. The scrapping of the greater part will no doubt be due to the fact that the progress of industry necessitates the replacement of many structures or appliances by others more economical or more accurate. But there nevertheless remains a large proportion amounting to millions of tons, the deterioration of which is due to corrosion alone, and when that tonnage is converted into terms of fuel consumed in its production the loss of combustible alone assumes startling proportions.

It seems paradoxical that stone and wood, though much less resistant to mechanical stresses than metal products, are much better able to withstand atmospheric influences. Moreover, it is a curious fact that as the demand for steel increases and as the capacity for its production on a large scale is ever growing, the relative amount annually wasted by corrosion also increases ; that is to say, with more intensive manufacture the inferiority of the product with respect to its resistance to corrosion appears to be on the increase.

This circumstance is well known to those who have to devote their attention daily to the products of our own time. It is a well-known fact that the iron and steel products of ancient origin were much less susceptible to atmospheric corrosion than are modern products, though none of them are entirely incorrodible, not even the famous column of Asoka at Delhi. This latter, which has remained unchanged for centuries, owes its preservation to a kind of fine coating, possibly slag, which originated in the process of manufacture, the removal of which would cause the pillar to corrode, though the progress of corrosion would be exceedingly slow.

That the atmosphere exerts a great influence is obvious from the fact that the common metals always occur as oxides, sulphides, sulphates, or carbonates, and scarcely ever as native metal, except those such as gold and platinum, which are not susceptible to atmospheric corrosion. The metallurgist in extracting the metal from its oxide is really exerting himself to undo that which the

slow action of the atmosphere has brought about, and although he has found a means of succeeding in this his triumph is apt to be short-lived, since the metal purified with such labour and expense soon tends to revert to the state of oxide, sulphide, sulphate, or carbonate from which it had been extracted.

On the other hand, it is evident that in the problem of corrosion readily corrodible substances may play an important part in this sense, that, since metallurgical products are never pure metals but are always alloys, it is evident that their chemical composition and their greater or less degree of homogeneity may be of influence in stimulating or delaying atmospheric action. It is equally certain that their physical state, microstructure, and condition of internal stresses are factors which influence the atmospheric effect to a greater or less degree.

Having thus sketched out the problem, it is clear that the subject is endowed with extraordinary interest, not only on account of the destruction of the iron, which if rusted can at all events be remelted and used again in some other form, but on account of the fact that the fuel consumed in its production can never be recovered, and no economic substitute is known at present.

In countries with progressive industries this fact has been recognised, and in recent years centres of research have been established to study the problem of corrosion. Numerous researches have been carried out at the Bureau for Testing Materials at Berlin and at the Institution subsidised by Carnegie in the United States. The Faraday Society in England has published a collection of reports thereon. In Germany a Committee known as the Reichausschuss für Metallschutz has been formed, whose organ, *Korrosion und Metallschutz*, summarises the results of corrosion research carried out in all countries.

In England the Institute of Metals, and in America the Institute of Mining and Metallurgical Engineers, devote themselves largely to the problem of corrosion, and publish results of research work thereon.

The Iron and Steel Institute, the most widely known organisation in regard to all that relates to the manufacture of iron and steel, follows the general rule. That Institute includes on its roll the leading metallurgists and chemists who have devoted

attention to this question of corrosion, and many important contributions on the subject are to be found in the pages of its publications.[1]

The results of all such work have become available to us in Spain, and some of the principal Spanish metallurgists and engineers are now manufacturing the so-called rustless steels. That is to say, the study of the problem of producing steels resistant to corrosion by external agents is definitely established as a national one in Spain.

Nevertheless, it is not this aspect of the problem which so much occupies the attention of the metallurgist at the present day, for if the only remedy against corrosion were to be found in the use of special non-rusting steels, the high cost of these would greatly restrict their application. The ordinary steel structures, such as bridges, structural steel for buildings, hulls of ships, railway material, &c., could never be built of such expensive material. The whole problem is a much wider one, and is not capable of so simple a solution. The main point is that any economic solution of the question must be such that will not raise the price of ordinary commercial steels above that at which they must of necessity be sold. It is this aspect of the problem which has been the subject of much study for several years, and upon which much has been written.

In the belief that the matter is one of special current importance, the authors venture to set forth briefly the theories of the corrosion of metals. They would mention as a singular coincidence, in support of which they have plenty of evidence, that in this country (Spain) the atmospheric conditions appear singularly adapted for producing their destructive effects.

Theories of Corrosion.—If among the elements of which the earth is composed the metals were simply in a state of metastable equilibrium—which as a matter of fact is never the case, since the metals always occur as oxides or salts due to their prolonged contact with natural agents such as water, oxygen, carbonic oxide, &c.—it is evident that the principal and true cause of such transformations would be atmospheric action alone. It is easy

---

[1] In June of the present year a committee on the corrosion of iron and steel has been constituted, which is a joint committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers, and it forms one of the technical committees of the Iron and Steel Institute.

PLATE XXI.

FIG. 1.—Strained steel.   Etched with picric acid.   ×120.

FIG. 2.—Same specimen as Fig. 1 after corrosion.   Polished only.
×120.

(The above micrographs have been reduced to ¾ in reproduction.)

PLATE XXII.

Fig. 3.—Annealed steel.   Etched with picric acid.   ×120.
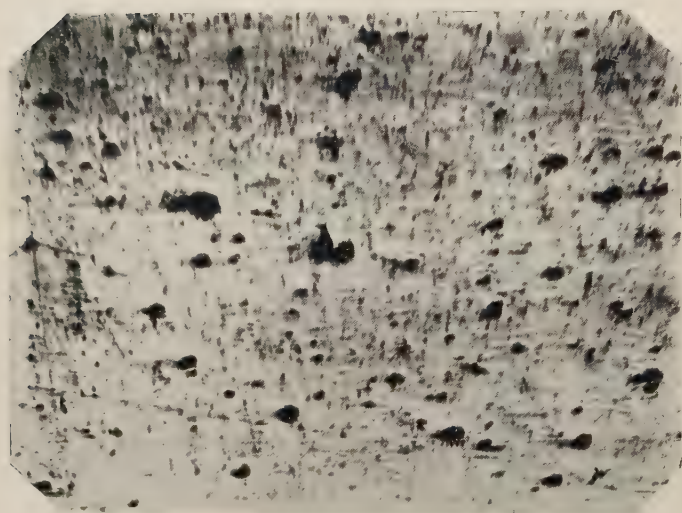
Fig. 4.—Same specimen as Fig. 3 after corrosion.   Polished only.
×120.

(The above micrographs have been reduced to ¾ in reproduction.)

PLATE XXIII.

FIG. 5.—Sorbitic steel. Etched with picric acid. ×120.
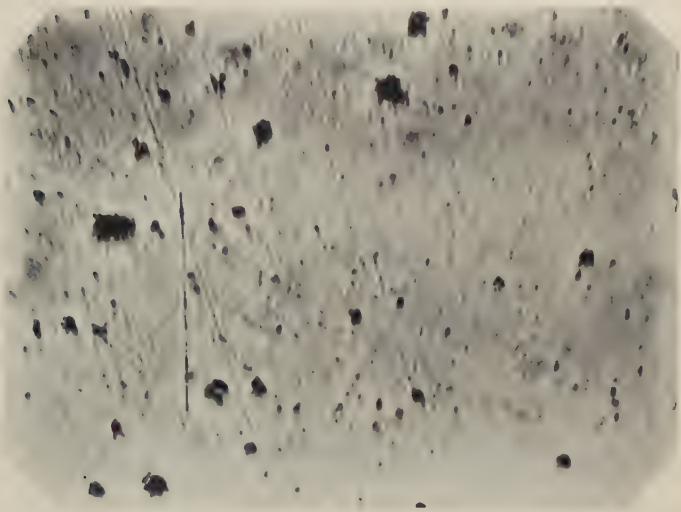
FIG. 6.—Same specimen as Fig. 5 after corrosion. Polished only.
×120.

(The above micrographs have been reduced to $\frac{3}{4}$ in reproduction.)

PLATE XXIV.

FIG. 7.—Steel with many slag inclusions after corrosion.   Polished
only.   ×120.
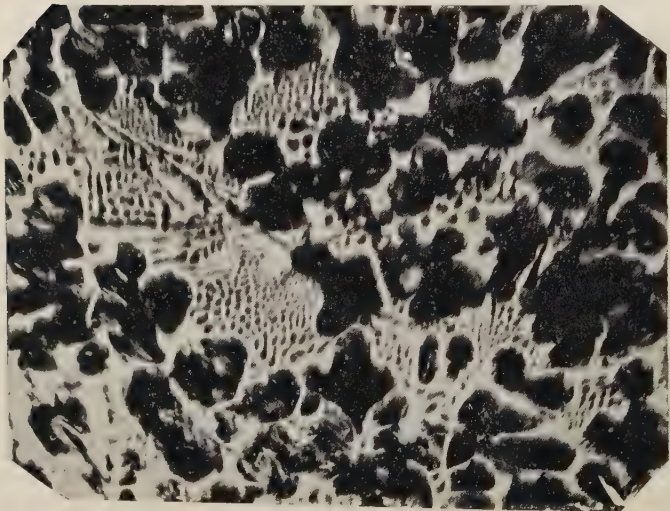
FIG. 8.—White iron.   Etched with picric acid.   ×120.

(The above micrographs have been reduced to ¾ in reproduction.)

PLATE XXV.

FIG. 9.—Same specimen as Fig. 8 after corrosion. Polished only.
×120.
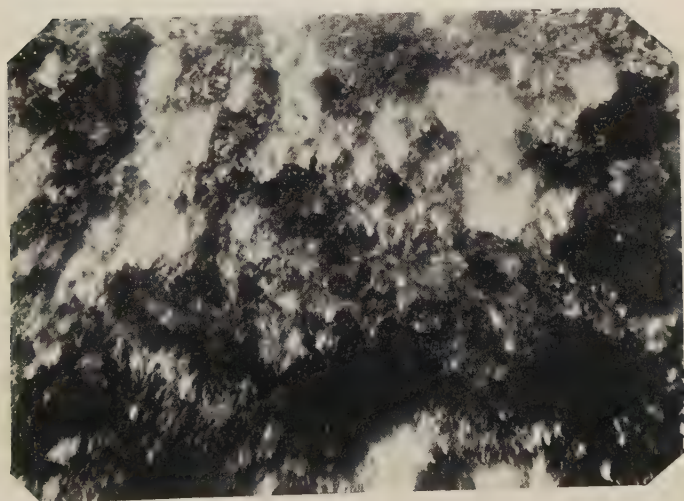
FIG. 10.—Specimen of a Rail after corrosion. Polished only. ×120.

(The above micrographs have been reduced to $\frac{3}{4}$ in reproduction.)

PLATE XXVI.

FIG. 11.—Sulphur print of the rail steel shown in Fig. 10 before corrosion.

(Reduced to $\frac{3}{4}$ in reproduction.)

PLATE XXVII.

FIG. 12.—Corrosion in a plate steel with striations. Polished only.
×120.

(Reduced to ¾ in reproduction.)

enough to indicate the disturbing element. The difficulty arises in defining how and when such action proceeds, and more particularly in determining the causes which tend to promote atmospheric action, causing a metal to lose its character and to change into a salt or an oxide, overcoming the inertia opposed to every such transformation, and, on the other hand, in finding the means for encouraging this inertia and thus impeding corrosion.

Two theories in explanation of the phenomenon of the corrosion of metals have found a following—namely, the electrolytic theory, held particularly in the United States by Cushman and Walker, and the chemical theory, championed in Europe by Heyn, Friend, and others.

According to the former theory, corrosion is due to the formation of local galvanic couples due to the existence in the steel of local differences of composition, impurities, or internal stresses. The defenders of the chemical theory, on the other hand, affirm that the oxidation of a perfectly pure and unstrained iron may take place in water without the intervention of any electrolyte whatever. Nevertheless, these latter admit that the absence of galvanic couples, when the before-mentioned causes to which they are due disappear, delays the initiation of oxidation but does not prevent it, once initiated.

Confining ourselves to practical facts, the three following fundamental propositions may be noted :

(1) That iron does not corrode in dry air, that is, unless moisture is present. Proof of this is afforded by the fact that in certain regions in Egypt and India, where the air is almost entirely lacking in moisture, metals do not corrode appreciably, while if the same articles are transported to other localities where the air is charged with moisture corrosion will set in at the ordinary intensity.

(2) That iron will not corrode even in moist air so long as no precipitation of water upon it occurs. Among other proofs of this fact perhaps the most striking is that steam turbine blades, working in superheated steam, are not subject to appreciable corrosion in those places at which the temperature of the steam, and in consequence that of the blades, is high enough to prevent the condensation of moisture upon them. On the other hand, corrosion is set up normally in other parts where the blades are

exposed to a temperature sufficiently low to enable the steam to condense upon them.

(3) That iron does not corrode in pure water if no air is present. The proof of this is the fact that any object of iron or steel partly submerged in water will corrode only slightly on the submerged part, but will suffer the maximum corrosion at the level of the water where it is subject to the simultaneous action of the oxygen of the air and of the water.

From the foregoing it may be inferred that to produce corrosion it is necessary always to have an agent which will attack iron—an electrolyte, in fact—and oxygen, and in addition free ions of hydrogen. Given this conception, both the chemical and electrolytic theories will harmonise perfectly, seeing that the former assumes the existence of those elements as being derived from an acid, and the electrolytic, admitting the ionic dissociation, leads to the same conclusion. For the water, however pure it may be, will always contain a small quantity of free hydrogen ions—that is to say, it will always be acid in character and action.

From this it may be agreed and admitted that the process of corrosion is always electro-chemical in character, the ionic theory being fundamental for its practical explanation, and in the academic sphere it may be left to the defenders of either theory to discuss the precise causes.

The authors do not propose to discuss fully the merits of the two theories of corrosion, as that would hardly be appropriate for a work of this character, for so much has been written on the subject of corrosion that to present the arguments in favour of or against these theories would fill volumes.

As a curious circumstance in this connection it may be mentioned that there is a biological theory which has found support in some quarters. That is, that corrosion of iron is to be attributed to certain micro-organisms, but although it is beyond doubt that cases of corrosion by organic agents have been met with, it does not appear that such agents could be nourished on iron. If such a thing were possible it would only be by bringing the iron first into solution by means of some acid secretion, which brings us back to the acid theory. Nevertheless, these curious cases have occurred in organic salts of iron, and the action of the micro-

organisms can only have been that of assimilating, not the iron, but the organic base of the salt, leaving the iron free in the form of ferrous hydroxide, thus exhibiting the phenomena which explain the acid and electrolytic theories of corrosion.

Electro-Chemical Phenomena.—Between any metal and a solution of a salt of the same metal of a known ionic concentration there exists a definite and precise potential at which there is equilibrium between both agents. That is, that at a certain voltage the metal will neither pass from the atomic to the ionic state, thus going into solution, nor will the metal that is in solution—that is, in the ionic state—deposit as metal in the atomic state. These potentials of equilibrium differ, as might be expected, from one metal to another, and they also vary within the same metal according to the ionic concentration, the temperature, the pressure, and the condition of the surface.

To render these potentials not only measurable but comparable, the potential of hydrogen is taken as the standard—namely, that which exists between platinum saturated with hydrogen and an acid solution of normal hydrogen-ion concentration at a pressure of one atmosphere. This standard of reference serves as zero in the scale of the electro-chemical series or electro-potentials of various metals.

Without going too much into detail, attention is directed to the accompanying Table I. showing the potentials referred to. The table shows that the " noble " metals occupy the highest position among the positive potentials, while the alkali metals are at the opposite extreme corresponding to the maximum negative potentials.

From this it is inferred that the noble metals are very easily reducible, for in whatever solution they exist they will precipitate, passing from the ionic to the atomic state, on being placed in contact with a metal of lower potential. The alkali metals, on the other hand, which belong essentially to the group of metals of high reactivity, when brought into contact with salts of other metals will dissolve readily, passing from the atomic to the ionic state.

It will be noticed that iron occupies an intermediate position in the electro-chemical series, but its potential is negative with respect to the hydrogen standard above referred to, and its negative character is sufficiently accentuated. It is, in fact, a

metal with a tendency to enter into ionic solution, and accordingly is susceptible to corrosion if the conditions are favourable.

TABLE I.—*Electro-Potentials of Various Metals.*[1]

Metal.	Ion.	Ionic Concentration.				
		N.	$N/10$.	$N/100$.	$N/1000$.	$N/10000$.
		Volt.	Volt.	Volt.	Volt.	Volt.
Gold . .	Au ⋅ ⋅ ⋅	+ 0·99(?)	...	...	...	...
Platinum .	Pt ⋅ ⋅ ⋅ ⋅	> + 0·86(?)	...	...	...	...
Silver. .	Ag ⋅	+ 0·7987	+ 0·741	+ 0·683	+ 0·625	+ 0·567
Mercury .	(Hg ⋅)₂	+ 0·7928	+ 0·764	+ 0·735	+ 0·706	+ 0·677
Copper .	Cu ⋅ ⋅	+ 0·3469	+ 0·318	+ 0·289	+ 0·260	+ 0·231
(Hydrogen).	H ⋅	± 0·000	− 0·058	− 0·116	− 0·174	− 0·232
Lead . .	Pb ⋅ ⋅	− 0·132	− 0·161	− 0·190	− 0·219	− 0·248
Tin . .	Sn ⋅ ⋅	− 0·146	− 0·175	− 0·204	− 0·233	− 0·262
Nickel .	Ni ⋅ ⋅	− 0·20	− 0·23	− 0·26	− 0·29	− 0·32
Cobalt .	Co ⋅ ⋅	− 0·23	− 0·26	− 0·29	− 0·32	− 0·35
Iron . .	Fe ⋅ ⋅	− 0·34	− 0·37	− 0·40	− 0·43	− 0·46
Cadmium .	Cd ⋅ ⋅	− 0·420	− 0·449	− 0·478	− 0·507	− 0·536
Zinc . .	Zn ⋅ ⋅	− 0·770	− 0·779	− 0·828	− 0·857	− 0·886
Aluminium	Al ⋅ ⋅ ⋅	− 1·337	− 1·356	− 1·375	− 1·394	− 1·413
Magnesium						
(approx.).	Mg ⋅ ⋅	− 1·8	− 1·8	− 1·9	− 1·9	− 1·9
Sodium .	Na ⋅	− 2·715	− 2·773	− 2·831	− 2·889	− 2·947
Potassium .	K ⋅	− 2·925	− 2·983	− 3·041	− 3·099	− 3·157

The electro-chemical phenomena thus outlined present features which will now be discussed in detail.

In some cases reversibility is almost perfect, that is, if the potential falls below the value necessary to maintain equilibrium, cathodic deposition takes place. If it is raised above that value anodic solution and corrosion set in. Both these phenomena proceed instantaneously without any lag according to the reagent which provokes the action—that is, there is nothing in the nature of electro-chemical hysteresis.

On the other hand, there are other cases in which, starting from a potential lower than that of equilibrium and increasing it by successive increments till it reaches and exceeds the equilibrium potential, an immediate reversal does not take place, for a higher potential than the equilibrium may be reached without anodic solution setting in. It will suddenly start after passing a zone of difference of potential which varies according to the

[1] U. R. Evans, *Transactions of the Faraday Society,* 1924, vol. xix. p. 797.

circumstances, this zone forming a regular hiatus in which no sensible electro-chemical action takes place.

In such cases an overvoltage is necessary to start anodic solution, and as soon as it has commenced the speed of solution falls off in spite of any increase of the voltage, until finally a state of passivity is reached.

One of the most interesting illustrations of this effect is afforded by the liberation of atomic hydrogen in the cathodic zones of any metal, iron for choice, for there then exists the hiatus referred to and the overvoltage is also necessary in order to overcome the inertia which causes the electro-chemical hysteresis. In the case of every metal this is a function of the state of its surface, of its electro-chemical history, of the temperature, and of the nature of the cathodic surface, the slightest roughness of which makes more easy the liberation of the hydrogen bubbles and reduces the overvoltage. The presence of a depolariser which, like oxygen, will combine with hydrogen will have the same effect. In all such cases the removal of the hydrogen in the one or other form will reduce the hysteresis, and to that extent will cause the electro-chemical phenomena to manifest themselves more readily. In developing their subject the authors wish to emphasise these characteristics, in view of the importance of the question of the corrosion of iron.

It may be clearly deduced that in order to produce the phenomena of corrosion it is essential that the electro-potential of hydrogen should be higher than the sum of the potential of the iron and the overvoltage imposed by the presence of the cathodic zone in which the bubbles begin to form. In the contrary case the current, and with it the corrosion, ceases.

Referring again to the table of the electro-chemical series, it follows in accordance with what has been stated that the electro-potential of the metals which occupy the lowest position in the series—that is, the alkali metals—is so small in comparison with that of hydrogen that their presence in an acid solution provokes the ready liberation of hydrogen, whereas in the case of the noble metals of a much higher electro-potential than that of hydrogen such a reaction is impossible.

Iron, as has been stated, occupies an intermediate position in the series, but the fact that its electro-potential is considerably

lower than that of hydrogen explains why the same thing occurs as with the alkali metals, though with less intensity. For the consequent overvoltage and hysteresis which may be caused by the presence of cathodic zones in the metal will tend to reduce the anodic solution of the iron—that is, the corrosion—if not check it altogether shortly after having set in, on account of the accumulation of bubbles of atomic hydrogen within such narrowly restricted zones. The cathodic zones referred to may be easily produced by strains in the product, or they may be due to the presence in the iron of other metals, metalloids, or impurities.

In such circumstances the reaction will continue if the liberation of hydrogen is facilitated ; but, on the other hand, the consequent overvoltage and the hysteresis would be so great that passivity would be reached and the corrosive action would cease. Thus the two types of corrosion which modern theories admit stand out with marked characteristics—that is, the corrosion with liberation of hydrogen in bubbles, and corrosion with elimination of cathodic hydrogen by means of a depolariser, which in general is oxygen, or in special cases may be some other oxidising agent. The first implies, nevertheless, a rapid displacement of hydrogen which would not take place unless acid solutions in contact with iron came into play. That, however, does not correspond to the normal process of corrosion in the wider sense, which is simply the corrosion produced by atmospheric agents under ordinary conditions.

It is this corrosion, in the full sense, and its effects which it is necessary to study and, if possible, prevent. It is nearly always of the second type indicated above—namely, that in which the removal of the hydrogen which accumulates in the cathodic zones is brought about by its combination with the oxygen of the surrounding air. Under such conditions an aeration, varying from one zone to another, might, in combination with other factors tending to set up corrosion, cause the rapid removal of the hydrogen in the aerated zones, which, being cathodic, will not be subject to corrosion so long as this phenomenon proceeds intensively and uninterruptedly in the anodic and non-aerated zones.

This explanation is nevertheless incomplete, unless account is taken of the phenomena which proceed in the anodic region, which is that of corrosion, even when on occasion the deposit

formed there is of so low a solubility that it covers the anode and protects it from further corrosion.

On the other hand, it is certain that the solution of the corrosion product will always leave the anode in a suitable condition for further attack. Thus in the case of iron and steel the presence of chlorides stimulates corrosion in a high degree, for the hydroxide of iron readily dissolves in hydrochloric acid.

Sometimes also the product of corrosion, when deposited upon the corroded surface, may become characteristic of the various forms of corrosion, for there is a marked difference between oxidation in the form of a thin but continuous coating, which, when once deposited, serves as a protective covering and hinders further attack (a typical example is the behaviour of the so-called non-oxidising steels) and a deposit of hydroxide of iron as a permeable and porous coating. In this case the action of the ions in furthering corrosion is limited to the pores of the deposited hydroxide, whereas the electrons can act on the entire surface of the coating. Thus is produced the type of corrosion called pitting, for it is only in these restricted zones that anodic solution can take place.

It may be concluded from all this that in the normal atmospheric corrosion of iron and steel the electro-chemical process will be regulated, given an even distribution of the oxygen, by the electro-potentials of the different parts. This point is emphasised, because an unequal distribution of oxygen may be of such intense influence as to disturb the course of the phenomena in question. In the first place, the presence of heterogeneity in the specimen is sufficient to cause corrosion, whether it be chemical in character (segregations of sulphur or phosphorus, or slag inclusions, presence of graphite, oxide inclusions, &c.), or whether of physical origin, as may happen with strained materials. In the first case just those zones will be cathodic where segregations, inclusions, or impurities are localised, and the remainder will be anodic. In the second instance the more strained zones will act as anodes and will dissolve, while the annealed or less strained zones will be cathodic.

The unequal distribution of the oxygen can, as indicated, completely change, or at least obscure, these results, softening the contrast which otherwise appears to delimit sharply the anodic and cathodic zones.

Causes of Corrosion.—From the foregoing it may be clearly judged that the causes producing corrosion are of two distinct types :

(1) Those which are independent of the object which suffers corrosion.
(2) Those which are a function of the physical or chemical properties of the object.

The first category includes, of course, those causes due to the surrounding medium in which the material happens to be placed, such as the following :

(1) Atmospheric conditions in general.
(2) Degree of contamination of the air or of the water by gases such as carbon dioxide which is very easily dissociated, or sulphur dioxide gas which has a very intensive corrosive action.
(3) Stray currents from electric circuits of high potential.
(4) Contact with other metals or with ferrous metals of different chemical composition.
(5) Faulty design.

In the second category the following causes may be mentioned :

(1) Local differences of composition due to non-metallic inclusions.
(2) Deposits, local or otherwise, of foreign bodies.
(3) Segregation of metalloids.
(4) Internal stresses or strains.

Having stated the causes of corrosion, the authors' work would be incomplete without some illustration of the manner in which the corrosion of iron and steel proceeds, and various typical specimens have been selected for macro- and micro-graphic examination.

The investigation being confined to the study of corrosion due to atmospheric agency alone, the specimens studied were exposed to atmospheric action after being well polished, contact with drops of moisture being carefully avoided, in order that the action of moist air alone should proceed very slowly, so as to

enable the particular effects to be followed step by step and the practical results to be noted at the proper moment. All the specimens were subjected to precisely similar tests.

Thus, for example, Figs. 1 and 2 (Plate XXI.) show that a strained steel, owing to an improper thermal and mechanical treatment, corrodes with much greater intensity than a similar steel that has been perfectly annealed (see Figs. 3 and 4, Plate XXII.). In Fig. 2, in the material after corrosion appears the banded structure which the original steel possessed (Fig. 1), while in the annealed steel, shown in Fig. 3, the corrosion, illustrated in Fig. 4, is much less, very much localised, and without any particular orientation.

It is evident that a sorbitic steel subjected to the same test, which when unstrained has a structure of the smallest grain-size, shows the same type of corrosion as the annealed steel, but of less intensity. Fig. 5 (Plate XXIII.) is a micrograph of the sorbitic steel in its original condition, and Fig. 6 shows it in the state of corrosion.

It may be concluded from these examples that improper mechanical hot-working, producing strains, or excessively large crystals, due to prolonged annealing, should be avoided if it is desired to reduce the effects of corrosion. Of the two defects, strains are of much the more decisive importance.

Fig. 7 (Plate XXIV.) shows the effect of the corrosion of a steel with many slag inclusions drawn out in the direction of rolling, and the conclusion is reasonable that with this orientation, prone to corrosion as previously noted and stimulated by the presence of non-metallic inclusions, the corrosion becomes rapid and intense. This shows up the necessity of avoiding everything that might lead to the formation of non-metallic inclusions, though in some cases these are the inevitable consequences of an elementary process of manufacture such as puddling, but in other processes they form serious defects which should be remedied, not only on account of the corrosion which they promote, but because they affect the mechanical properties—which question, however, is outside the subject of the present paper.

The presence of sulphur in iron and steel always stimulates intense corrosion. This is evident from Figs. 8 and 9 (Plates XXIV. and XXV.), which are micrographs showing a

white iron and its appearance after corrosion. The first micrograph shows the eutectic of iron and sulphide of iron clearly defined, and the second the degree of corrosion attained.

Fig. 10 represents the result of the corrosion of a rail, the only cause which has stimulated corrosion being the marked segregation of sulphur, as brought out clearly on the corresponding sulphur print, Fig. 11 (Plate XXVI.). The intensity of the action of sulphur in activating corrosion will be noted.

Micrograph Fig. 12 (Plate XXVII.) likewise affords evidence of an important occurrence in the manufacture of certain products, such as plates. The striations, however small they may be, exert a radical influence owing to their forming zones of corrosion and thereby promoting it, as was pointed out in discussing electrochemical phenomena. Care should therefore be taken to use hard rolls, perfectly true, and well polished. This point is of the greatest importance for any structures exposed to sea-water.

Means for Moderating the Effects of Corrosion.— Once the causes producing corrosion are known, it becomes possible to consider the remedies that may be applied to avoid it or restrict it within limits. Concentrating first on the external causes, it is outside our power to alter the atmospheric conditions, or to prevent contamination of the air by carbon dioxide or sulphur dioxide gases, which necessarily abound in metallurgical works on account of the combustion of fuel on a large scale therein. Preventive action can only be taken to meet the cases set forth in paragraphs : (3), the attack by stray currents of high potential ; (4), attack due to the use of metals of different chemical composition ; and (5), attack due to defects in design (p. 120). With regard to Nos. 3 and 4, it is difficult to find an efficacious remedy ; for example, in the case of the metal supports of the transmission lines of high-tension electric current, leakages of current, due to defective insulation, are not infrequent, and are difficult to prevent. Likewise in the manufacture of machinery, contact between different metals giving rise to corrosion is inevitable.

With regard to defective design, it has repeatedly been found that in a steel structure the main components have for the most part been perfectly calculated to withstand the mechanical stresses which they are intended to bear, but that by some error certain principal members have been miscalculated, with the

result that the material in parts is stressed beyond its elastic limit. Under such conditions the parts so stressed, which may be very important members of a framework, are highly liable to corrode even though the remainder may remain normal, and thus the stability of the entire structure may be impaired. It has happened that the whole structure has had to be taken down and replaced through failure to recognise this danger.

It has also happened in the case of a structure perfectly designed from the point of view of resistance to the mechanical stresses that rain water may accumulate in hollow spots and remain a long time without draining off, and if such spots are not easily accessible it may not be easy to keep them properly painted or remove any coating of rust which may have formed on the steel structure. All such cases show the importance of the study of corrosion from the point of view of safety, and how the rusting of a small and insignificant part may lead to the destruction of the whole structure.

Concerning the general atmospheric conditions, it is evident that a moist air and persistent exposure to rain with strong aeration are agents which particularly favour corrosion, since both the electrolyte and influence of oxygen then come into action.

If to these conditions be added that of proximity to the sea, bringing with it air laden with sodium chloride which increases the conductivity of the electrolyte and consequently accelerates the corrosion, it will be readily understood that the metallurgical works of Vizcaya are unfortunately exposed to a combination of all the circumstances most apt to produce intensive corrosion due to external causes. The industrialists of Vizcaya are only too well aware of this trouble in their district. Nevertheless, since the same disadvantages are prevalent in nearly all British and American ironworks, and in many works in Germany, it may be said that the trouble is universal and is inherent to the conditions under which the metallurgical industry is carried on.

With regard to the internal causes which stimulate corrosion, it has already been indicated in what direction the remedy should be applied in each case. Proper heat treatment and mechanical treatment, the elimination of impurities and avoidance of segregations, are the principal objects to aim at to obtain improvement.

All non-metallic inclusions contained in steel, whether gaseous or solid, are impurities and defects which need never be present if sufficient care be taken in the manufacture of the steel, and the same applies to surface deposits of foreign substances.

It is undeniable that a suitable heat and mechanical treatment will remove strains from steel, and it is equally true that the removal of the segregating metalloids, sulphur and phosphorus, particularly sulphur, will improve the rust-resisting qualities of the metal.

The authors emphasise with genuine satisfaction, both as Spaniards and as promoters of knowledge on this subject, that their metallurgical works are fully equipped with all the elements of precision for the study of any problem which may arise within this field.

Finally, if the statements in this paper on the subject of corrosion should serve as a means of inducing both the scientific gentlemen among the members who honour us with their visit, and our own scientists who have specialised on the subject, to exchange the results of their latest studies, the authors will consider that they have achieved their principal ambition in presenting this paper.

DISCUSSION.

Professor CARL BENEDICKS (Stockholm), in opening the discussion, said that the authors, in their very complete paper, had referred to the famous iron pillar at Delhi, which was described by Sir Robert Hadfield in one of his communications to the Institute.   The authors stated on p. 110 that its preservation—during something like fourteen centuries—was due to a kind of fine preservative coating which originated in the process of manufacture.   It was perfectly true that such a coating was known to be preservative at least for some time.   Generally, however, corrosion set in at some definite point where the coating was weaker, as explained in the paper, and at that point the corrosion was even greater than if the preservative coating were not present, generally due to electrolytic action.   If, on the other hand, the coating could be automatically renewed, the preservative action was of a reliable nature.   The question arose whether in the tropical climate of India and elsewhere some factor existed which gave rise to the formation of some protective coating.   It occurred to him that such a factor might be present in tropical countries, due to the fact that the rain-water contained more nitric acid than in cooler climates. That, as was well known, was due to the heavy tropical thunder-storms—which were very heavy in the region of the Himalayas.   With regard to the action of nitric acid, it had been well known since the end of the eighteenth century that concentrated nitric acid rendered iron passive or non-corrodible.   He, with Mr. P. Sederholm, had recently made some experiments in connection with the action of very dilute nitric acid, and he believed the results might be of some interest to the members, although they were not designed in any way in connection with the paper under discussion.   The highly diluted nitric acid used contained $0 \cdot 1$ per cent. of nitric acid in ethyl alcohol, to which different amounts of water were added.   The metal used was a $0 \cdot 9$ per cent. carbon Swedish steel containing spheroidised cementite and scarcely any visible slag particles.   A prolonged time of etching (20 minutes) was used.   In a solution which contained only a small amount of water there was a rather weak dissociation of the acid.   The addition of slight quantities of water had the object of rendering the electrolytic dissociation stronger.   The first specimen was etched in a very weak solution.   The result was that the struc-ture of the metal—which otherwise was very uniform—showed large unetched regions ; attack appeared only on some parts.   The reason for that was the formation of a partly preservative layer on the surface of the metal.   On increasing the water content, it was found that the etched regions were generally somewhat larger than in the former case, and at the same time it was found that the thickness of the

preservative coating had increased. That was demonstrated by the fact that the coating showed beautiful Newton colours. Besides that, the thickness was emphasised by the occurrence of plain drying cracks. Time would not permit him to enter into further details ; it was sufficient to say that if a certain quantity of water were added the formation of a preservative coating no longer occurred. With regard to the action of the rain-water, the quantity of nitric acid in rain-water was very low indeed, but it might have the effect of producing a protective coating. Summing up, it was assumed, even by Faraday, that the action of concentrated nitric acid in producing passivity was due to a protective coating ; the experiments now mentioned showed that such a protective coating could be produced even by a very dilute nitric acid. He thought, therefore, the conclusion might be justified that the preservation of the remarkable Delhi pillar might be ascribed to the action of the rain.

Sir WILLIAM LARKE, K.B.E. (London), said that as a member of the Corrosion Committee of the Institute he welcomed the paper very much indeed, and desired to emphasise its concluding paragraph in which the authors urged upon all metallurgists, and particularly the members, the desirability of co-operation by exchanging their results and experiences in regard to corrosion. He appealed to all the members to make a point of communicating to the Secretary of the Institute any results they might obtain, or any views they might hold with regard to corrosion, in order that the work of the Corrosion Committee might be made of real value to the industry.

Mr. J. HENDERSON (Member of Council) desired in the first place to congratulate the authors on the manner in which they had dealt with a very difficult subject. It was impossible for him to follow Professor Benedicks in his technical examination of the theories of corrosion in general, or of the iron pillar at Delhi in particular— in fact, he desired to confine his few remarks to a general consideration of the subject. In the middle of p. 110 the statement was made : " Moreover, it is a curious fact that as the demand for steel increases and as the capacity for its production on a large scale is ever growing, the relative amount annually wasted by corrosion also increases ; that is to say, with more intensive manufacture the inferiority of the product with respect to its resistance to corrosion appears to be on the increase." He hesitated to challenge the considered opinion of the authors of such an able paper, but he desired to say as a practical man, with many years' experience in the manufacture of steel in England, that he could not subscribe to the truth of the paragraph he had quoted, so far as his experience went. He felt that during the past 25 years there had been a very steady increase in the technical development of their processes, and that steel was now being produced which was very much freer from impurities of a metalloid character

such as sulphur and phosphorus, and also from the oxides and other inclusions which were always present to a greater or less extent. Corrosion, as the authors stated, whether it occurred according to the electro-chemical or the purely chemical theory, centred round those impurities, and he maintained that there had been a steady improvement in that respect, at any rate so far as his own experience in England went. Although it was not clear proof of his conviction, he stated that for several years past in the works with which he was connected experiments had been made with steel containing a small percentage of copper which was much used in the United States and elsewhere for the purpose of reducing the rate of corrosion, and the results so far obtained had been entirely negative—that is, the copper steel had not given any better results than the other steel. It was extremely difficult to set up any particular standard for the rate of corrosion, as it was obvious that every set of circumstances making for corrosion differed enormously, so that the experiments to which he had referred were by no means conclusive. He felt, however, that at the present time a higher quality of steel, particularly in the Siemens-Martin process, was being produced than previously, and that to that extent a steel was being manufactured that would be less subject to corrosion.

CORRESPONDENCE.

Mr. F. H. Simms (Wednesbury) wrote : I have read the authors' paper on the corrosion of iron and steel with great interest. As an ironmaster, it appears to me regrettable that under such a comprehensive heading greater distinction is not made between true steel and wrought iron. Judging from the illustrations, the specimens studied appear to have been exclusively steel, and some of the conclusions would appear to apply to steel only and not to wrought iron. For instance, the following passages occur :

". . . the presence of heterogeneity in the specimen is sufficient to cause corrosion, whether it be chemical in character (segregations of sulphur or phosphorus, or slag inclusions, presence of graphite, oxide inclusions), or whether of physical origin, as may happen with strained materials. . . ."

" Fig. 7 (Plate XXIV.) shows the effect of the corrosion of a steel with many slag inclusions drawn out in the direction of rolling, and the conclusion is reasonable that with this orientation, prone to corrosion as previously noted and stimulated by the presence of non-metallic inclusions, the corrosion becomes rapid and intense. This shows up the necessity of avoiding everything that might lead to the formation of non-metallic inclusions, though in some cases these are the inevitable consequences of an elementary process of manufacture, such as puddling. . . ."

It is well known in practice that puddled wrought iron resists corrosion in its commonest forms much better than mild steel, and this is generally attributed to the fact that each globule of iron, from the moment of its " coming to nature " in the puddling furnace, is surrounded and protected by a thin film of slag or silicate.   This slag is non-corrodible, and, being practically a non-conductor of electricity, also acts as an insulator.

Whatever be the true theory of corrosion, experience of the use of steel in place of wrought iron during the post-war period has in many cases proved an expensive failure, as is proved by the fact that in 1923 a special committee, known as the Wrought Iron Tubing Enquiry Committee, was set up by the Institution of Gas Engineers, to investigate the question of corrosion in service pipes.   In view of their recommendation that " in future only wrought iron of superior quality " should be used, an official specification was drawn up and adopted by the Institution in February 1927, requiring that only genuine puddled iron should be supplied to the industry.

One of the best-known examples of the superiority of puddled iron for resisting corrosion is to be found in the corrugated steel sheet roofs and buildings put up since the war, many of which are in an advanced stage of decay, or have already been replaced, while old iron sheets put up 20 years before the war are still in sound condition and doing good service.   It is well known too that in proximity to the sea wrought iron, despite included non-metallic impurities, will last much longer than steel.   As an instance of this the under-frames of railway fish wagons in Great Britain are nearly always specified in wrought iron, although ordinary dry goods trucks are now largely built of steel on account of its lower cost.

Dr. Newton Friend's recent experiments in the Bristol Channel, on the relative corrodibilities of iron and steel,[1] give the following interesting figures :

	No. of Specimens Tested.	Relative Corrodibility.
Wrought iron	11	100
Cast iron	4	112
Mild steel	9	126

It would be interesting to know how the authors reconcile the foregoing facts with the statements quoted above from their paper. These statements appear to me to cast an unjustifiable reflection on puddled wrought iron, which, if allowed to pass, may cause injury to one of the country's oldest and still most important industries.

The AUTHORS wrote, in reply, that they desired to express their cordial thanks to those who had shown their interest in the paper by contributing to the discussion.   They considered they might with

---

[1] *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1927, vol. xvi. pp. 131–151.

advantage offer some remarks in explanation rather than in reply, in order to define more clearly their point of view on the subject in question.

Professor Benedicks was of opinion that the slow corrosion of the Delhi pillar might be due principally to the presence of dilute nitric acid in the rain-water in those tropical regions. If such acid were actually present, it would without doubt suffice to produce in a greater or less degree a state of passivity in the iron. The authors were quite ready to accept such an opinion from so distinguished an authority, but for the fact that others qualified to judge, such as Hadfield and Rosenhain, were inclined to attribute the slow corrosion to the presence of some kind of slag coating which afforded a certain amount of protection to the pillar against atmospheric action, and more particularly to the circumstance already proved that a dry atmosphere uncontaminated with gases would certainly minimise the effects of corrosion to a very marked degree.

The authors were strengthened in that theory by the observations of U. R. Evans, who had drawn attention to the fact that in Alpine regions all fortifications and defences constructed of steel during the war of 1914–18 showed very little sign of any corrosion when he examined them in 1923, notwithstanding that no very scrupulous care had been exercised in the manufacture of the material. In Evans' opinion the absence of condensation of moisture upon them, due to the low temperature, and in particular the very pure atmosphere of those regions afforded a sufficient explanation of the almost inappreciable amount of corrosion. He mentioned the further fact, well known to Alpinists, that all iron crosses placed on peaks or high up among the mountains showed no appreciable degree of corrosion.

That coincidence of cause and effect in the case of the Delhi pillar and of iron structures in the high Alps notwithstanding the great difference in climatic conditions, induced the authors to hesitate in accepting the opinion of Professor Benedicks until he might be in a position to bring forward definite evidence in support of his theory.

It was perfectly true, as Mr. Henderson observed, that in England the steel-making processes had improved greatly in the last 25 years, and possibly his wide experience inspired him with optimism concerning the problem of corrosion. The authors regretted that they were unable to share his optimism in an equal degree at the present moment, seeing that in other countries they were not so fortunate in having such an excellent choice in the quality of their raw materials as in England, which was more especially favoured in that respect than any other country in the world. Actually it was not only in Spain but in all other countries, including England, in spite of the progress of 25 years, that the trouble existed, as revealed by the closing words of the Presidential Address delivered by the eminent metallurgist Mr. Benjamin Talbot, present President of the Iron and Steel Institute. That the problem was still as urgent in England as anywhere else was indicated by the fact that in June of the present year a Committee was formed

in that country, especially charged with the study of the phenomena of corrosion, and Sir William Larke referred to the work of that Committee, at the same time calling for the collaboration of all other countries in helping to solve the important problem of the prevention of corrosion.

Finally, the authors would observe that in studying the phenomena of corrosion and endeavouring to investigate the means for preventing its destructive effects they had confined themselves strictly to the question of steel and had not considered puddled iron, since they recognised, as stated by Mr. Simms, that puddled iron products were more resistant than steel to the corrosive action of atmospheric agents and other factors which stimulated corrosion. Nevertheless, on account of its lower resistance to mechanical stress the application of puddled iron was very restricted, and the metallurgical industry could not expect by its use to find a remedy against the ravages of corrosion.

On that account every research aiming at the study of corrosion in its relation to metallurgical products must be directed to remedying the corrosion of steels, since those, and not puddled iron, were now almost exclusively employed in constructional and engineering work.

THE INFLUENCE OF PEARLITISATION BE-LOW THE Ar₁ POINT ON THE MECHANICAL PROPERTIES OF CARBON STEELS.[1]

By JOAQUIN ORLAND (Madrid).

It is a well-known fact that if a piece of steel be rapidly cooled from a temperature above Ac_3 to a temperature below Ar_1, a precipitation of the constituents ferrite and cementite takes place in a degree varying according to the cooling speed and the temperature at which the cooling is stopped.

Hallimond,[2] in a paper on " Delayed Crystallisation in the Carbon Steels : the Formation of Pearlite, Troostite, and Martensite," represents in a diagram the metastable range and the labile " shower precipitation." It is clearly shown by this diagram that below the austenite-ferrite and austenite-cementite equilibrium curves the eutectoid is formed by " inoculation," whatever may be the temperature below Ar_1, provided it is above the supersolubility curves.

Very fine pearlite is produced if the cooling be stopped near the supersolubility curves at which the labile shower takes place. The nearer these curves are approached the finer will be the pearlite obtained.

If the cooling be continued below the supersolubility curves in the actual range of these curves, very fine grains of ferrite and cementite are separated. This precipitation is called by Hallimond the " labile shower." A region of suspended crystallisation is found below 100° C., as beyond this temperature austenite undergoes little, if any, crystallisation.

In tempering a quenched steel there is no corresponding critical change, as in this heating process only grain-growth of ferrite and agglomeration of carbide will take place. This grain-growth and agglomeration give rise first to the formation of

sorbite, and then of globular pearlite, more or less fine, according to the temperature and the time.

It seems evident that by tempering under suitable conditions of temperature and time a pearlite can be obtained as fine as that produced by normalisation, and with a higher ultimate strength. This higher ultimate tensile strength is undoubtedly due to the manner in which pro-eutectoid ferrite is separated in hypo-eutectoid steels, because this ferrite separates freely during normalisation, whereas during tempering precipitation begins at the same time at many points (" labile shower "), the pearlite thus obtained being much finer. The same thing occurs, though partially, in lower carbon steels.

If the tensile strength so obtained is higher, and the impact number is also higher, or, at least, not lower, the mechanical properties of the steel will have been improved.

The purpose of this paper is to give an account of the results of experiments with some carbon steels of various carbon contents, comparing the mechanical properties of laminar pearlite in normalised steel with very fine globular pearlite obtained in the same steels by tempering.

The steels employed in this study are : a Bessemer steel containing 0·155 per cent. of carbon from the Altos Hornos de Vizcaya, and five specimens of steel with varying percentages of carbon from the Reinosa Works of the Sociedad Española de Construcción Naval. Table I. gives the analyses of these steels, B15 being the Bessemer steel.

TABLE I.—*Analyses of the Steels Tested.*

Specimen No.	Carbon. %	Manganese. %	Silicon. %	Phosphorus. %	Sulphur. %
B15	0·155	0·40	0·056	0·065	0·044
N15	0·15	0·55	0·15	0·038	0·022
N32	0·32	0·71	0·16	0·032	0·012
N58	0·58	0·68	0·14	0·019	0·021
N84	0·84	0·20	0·20	0·028	0·030
N105	1·05	0·57	0·28	0·021	0·019

For the tensile tests a universal Amsler 50-ton machine was employed ; for the impact tests a 100-kg.-m. Charpy machine,

and for the fatigue tests a Wöhler (single point loading) machine by Avery, were used. Observations of fatigue were made by the strain method. No comparison has been made of the results thus obtained with results arrived at by the long-time fracture
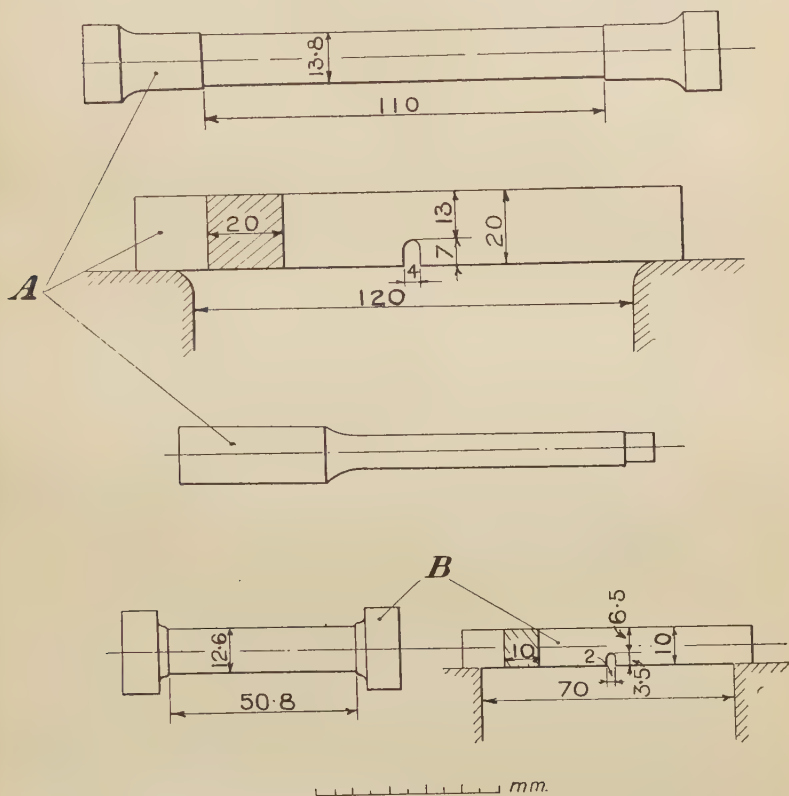
FIG. 1.—Forms of Test-Pieces employed in this Investigation.

method, as it was only intended to make a comparison between the pearlitic structure obtained by normalisation and that obtained by tempering. Test-pieces of the form shown in Fig. 1, *A*, were employed in all tests, except in the case of steel *N*84, for which bars of the shape illustrated in Fig. 1, *B*, were used.

*B*15 (*Bessemer Steel*).—Nineteen test-pieces—seven for tension, six for impact, and six for fatigue—were cut out of a 30-mm.

diam. round bar without forging it. One of them, *B*15–7 in
Table II., was tested without any further treatment. The other
eighteen were treated as shown in Table II., in which are also
to be found the mechanical properties given by the tests. The
Brinell impressions referred to in this table and in the others
were all taken on the impact test-piece.

TABLE II.—*B*15.   *Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress, Kg. per sq. mm.	Elastic Limit, Kg. per sq. mm.	Elongation, %	Reduction of Area, %	Brinell Hardness Number.	Impact Value, Kg.-m. per sq. cm.	Fatigue Limit, Kg. per sq. mm.
*B*15–1	(Air-cooled from	44·6	32·0	34·0	52·6	128	22·6	± 34
*B*15–2	{ 880° C. }	45·0	31·0	33·5	63·2	128	14·0	± 36
*B*15–3	(W.-Q. 880° C., { T. 750° C. for	42·8	27·0	36·6	66·5	126	1·5	± 36
*B*15–4	2 hr.; cooled { in furnace	42·7	30·0	32·0	68·0	124	1·5	± 34
*B*15–5	(W.-Q. 880° C., { T. 500° C. for	53·6	36·0	31·0	65·5	162	15·0	± 41
*B*15–6	2 hr.; cooled { in furnace	54·0	36·0	25·0	67·0	156	16·0	*
*B*15–7	Untreated .	44·7	30·0	34·0	65·0	...	...	...

W.-Q. = water-quenched ; T. = tempered.

* Broke during treatment.

A glance at this table clearly shows that the treatment
given to the test-pieces 3 and 4 has lowered their mechanical
properties. This treatment—merely an annealing just above
the A$_1$ point—has diminished both the ultimate strength and the
impact number, the latter to a high degree. This, undoubtedly,
is due to the low percentage of pearlite in this steel. Since pearlite
hinders the recrystallisation of ferrite, the grains thereof have
freely grown from the temperature of 500° C. For this reason
the temperature of 500° C. was chosen for the specimens 5 and 6,
so obtaining a higher ultimate strength and impact number. It
cannot be determined whether the impact number for specimens
5 and 6 is higher or lower than that of specimens 1 and 2, owing
to the diverse results given by the latter.

Figs. 2 and 3 (Plate XXVIII.) show the fractures of the impact test-pieces from B15–1 and B15–6; Figs. 11 and 12 (Plate XXX.) illustrate the microstructures of the same specimens.

Steel N15.—This, as well as the following specimen, is an electric furnace steel. Of this one a round bar 30 mm. in diameter and 1000 mm. in length was forged in order to get the before-mentioned test-pieces. The treatment and the results obtained are recorded in Table III. :

TABLE III.—*N15.* *Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress. Kg. per sq. mm.	Elastic Limit. Kg. per sq. mm.	Elongation. %	Reduction of Area. %	Brinell Hardness Number.	Impact Value. Kg.-m. per sq. cm.	Fatigue Limit. Kg. per sq. mm.
N15–1	Air-cooled from 850° C.	45·9	27·0	42·2	60·7	126	22·8	± 29
N15–2	W.-Q. 850° C., T. 500° C. for 2 hr.; cooled in furnace	58·8	35·0	11·55	56·0	177	21·2	...
N15–3		60·0	35·4	11·90	63·0	167	24·0	± 33

W.-Q. = water-quenched; T. = tempered.

Steel N32.—This steel was received in the form of a rolled bar 80 mm. in diam. and 1010 mm. in length. Out of this bar test-pieces were obtained by forging. In order to avoid stresses that might remain after forging, all the pieces were annealed before machining. (This was done with all the forged test-pieces.) Table IV. shows the treatment and mechanical properties of this steel.

Specimens 3 and 4 of this steel each had higher ultimate tensile strength and a little lower impact number; the treatment given to specimen 5 seems to be the best.

Test-pieces 3 and 4 were put into the cold furnace, and the temperature was raised up to 550° C.; the heating was then stopped, so that after 10 to 15 minutes its temperature was 500° C., where it remained for the following two hours.

Fig. 4 (Plate XXVIII.) represents the fracture of the impact test-piece of N32–5. Fig. 13 (Plate XXX.) shows the

microstructure of the same steel ; as can be seen, the pearlite is much finer and there is a much lower proportion of free ferrite.

TABLE IV.—*N*32.   *Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress, Kg. per sq. mm.	Elastic Limit. Kg. per sq. mm.	Elongation. %	Reduction of Area. %	Brinell Hardness Number.	Impact Value. Kg.-m. per sq. cm.	Fatigue Limit. Kg. per sq. mm.
*N*32–1	⎧ Air-cooled from	55·8	31·0	23·0	49·3	156	14·1	± 30
*N*32–2	⎩ 810° C.	55·0	31·0	25·0	57·0	166	14·0	± 34
*N*32–3	⎧ W.-Q. 810° C., ⎫ T. 500° C. for	71·0	45·0	12·5	53·0	241	13·5	± 44
*N*32–4	⎨ 2 hr. ; cooled ⎬ in furnace	72·3	46·0	15·5	51·0	241	13·4	± 43
*N*32–5	W.-Q. 810° C., T. 580° C. for 2 hr.; air-cooled	67·0	43·2	18·5	65·7	203	18·2	...

W.-Q. = water-quenched ; T. = tempered.

*Steel N*58.—Out of a bar of this steel, 58 mm. square and 880 mm. in length, test-pieces were forged and annealed as in the former case.   Table V. gives the results of the tests.   Selected

TABLE V.—*N*58.   *Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress, Kg. per sq. mm.	Elastic Limit. Kg. per sq. mm.	Elongation. %	Reduction of Area. %	Brinell Hardness Number.	Impact Value. Kg.-m. per sq. cm.	Fatigue Limit. Kg. per sq. mm.
*N*58–1	⎧ Air-cooled from	70·0	33·0	14·0	39·7	209	7·3	± 34
*N*58–2	⎩ 780° C.	71·5	35·0	15·0	26·0	223	6·3	± 37
*N*58–3	⎧ W.-Q. 780° C., ⎫ T. 500° C. for	81·0	53·0	4·0	26·6	307	7·9	± 60
*N*58–4	⎨ 2 hr. ; cooled ⎬ in furnace	91·0	64·0	6·0	39·0	399*	5·4*	± 56
*N*58–5	W.-Q. 780° C., T. 580° C. for 2 hr. ; air-cooled	81·5	76·0	17·0	51·3	248	13·6	...

W.-Q. = water-quenched ; T. = tempered.

* Impact test-piece *N*58–4 was held at 500° C. for only 20 minutes and was then immediately left to cool in the air. This was, no doubt, the cause of the lower impact value and higher Brinell number.

PLATE XXVIII.

Fractures of Impact Test-pieces.   Magnification 1·7 diameters.
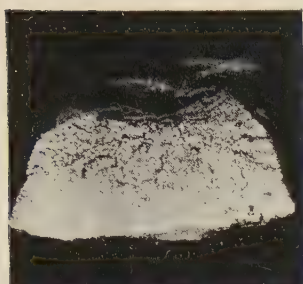
FIG. 2. — B15–1.   Air-cooled from
880°C.
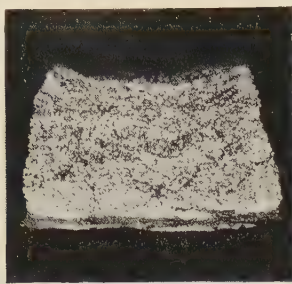
FIG. 3.—B15–6.   W.-Q. 880°C., T.
500°C., cooled in furnace.
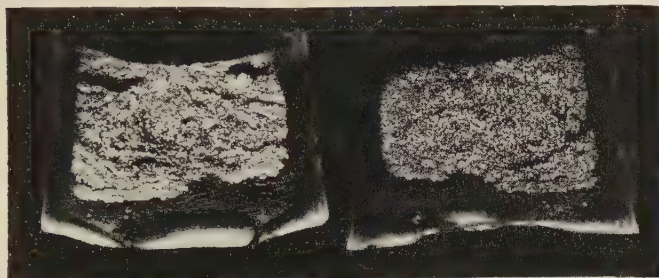
FIG. 4.—N32–5.   W.-Q. 810°C., T. 580°C., air-cooled.
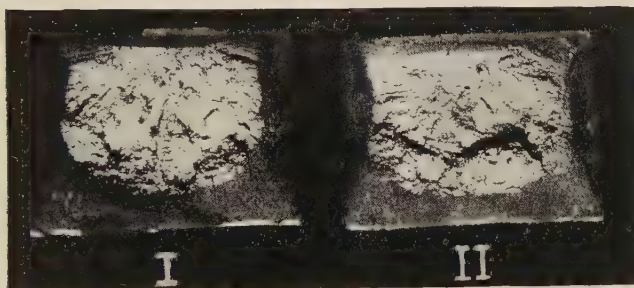
FIG. 5.—I. N58–3.   II. N58–4.   W.-Q. 780°C., T. 500°C., cooled in furnace.
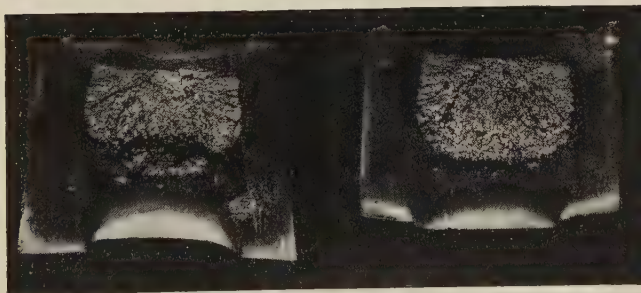
FIG. 6.—N58–5.   W.-Q. 780°C., T. 580°C., air-cooled.

W.-Q.=water-quenched; T.=tempered.
NOTE : All the above temperings were of 2 hr. duration.

PLATE XXIX.

Fractures of Impact Test-pieces. Magnification 1·7 diameters.

FIG. 7. — I. *N*84–1. Air-cooled from 760°C. II. *N*84–2.
W.-Q. 760°C., T. 500°C., cooled in furnace.
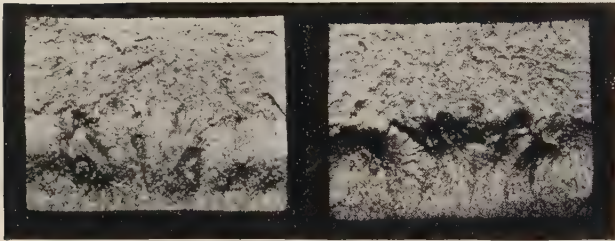
FIG. 8.—*N*105–2. Air-cooled from 760°C.
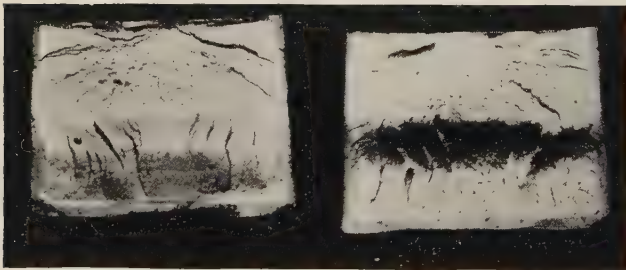
FIG. 9.—*N*105–4. W.-Q. 760°C., T. 680°C., cooled in furnace.
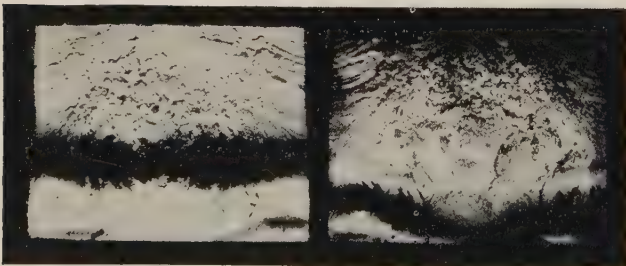
FIG. 10.—*N*105–5. W.-Q. 760°C., T. 500°C., cooled in furnace.

W.-Q.=water-quenched; T.=tempered.

NOTE : All the above temperings were of 2 hr. duration.

PLATE XXX.

Microstructures of Test-pieces. Magnification 1000 diameters (reduced to $\frac{2}{5}$ in reproduction).
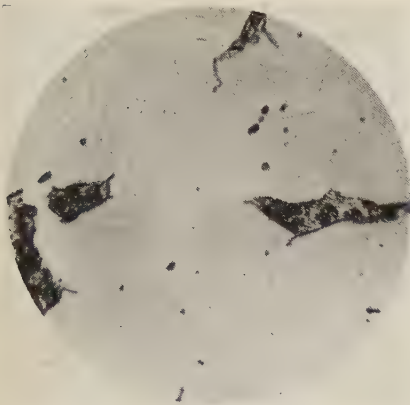
FIG. 11.—*B*15–1. Air-cooled from 880°C.
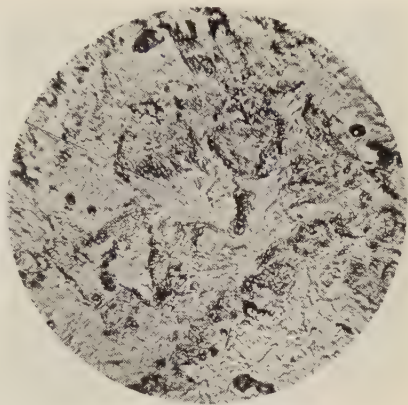
FIG. 12.—*B*15–6. W.-Q. 880°C., T. 500°C., cooled in furnace.
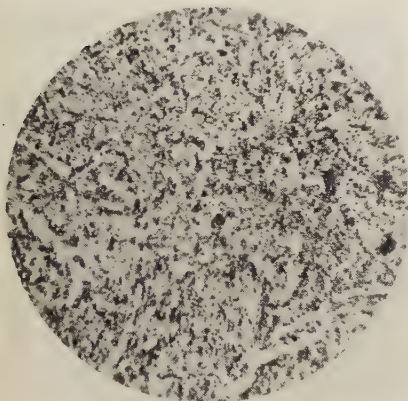
FIG. 13.—*N*32–5. W.-Q. 810°C., T. 580°C., air-cooled.
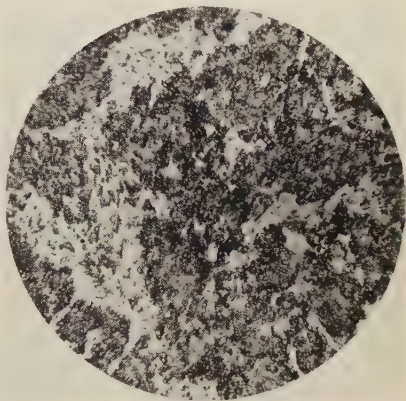
FIG. 14.—*N*58–3. W.-Q. 780°C., T. 500°C., cooled in furnace
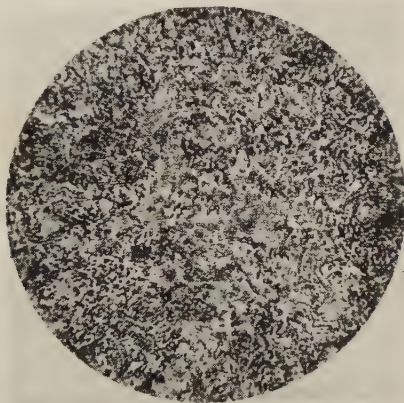
FIG. 15.—*N*58–5. W.-Q. 780°C., T. 580°C., air-cooled.

W.-Q.=water-quenched ; T.=tempered.

NOTE : All the above temperings were of 2 hr. duration.

PLATE XXXI.

Microstructures of Test-pieces. Magnification 1000 diameters (reduced to ⅔ in reproduction).
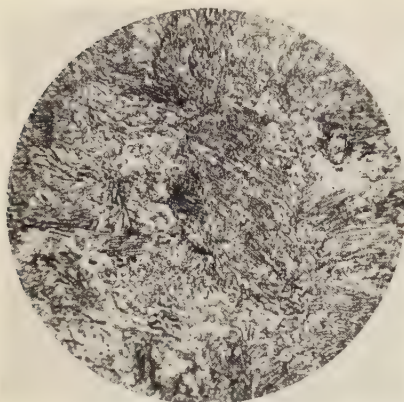
FIG. 16.—*N*84-1. Air-cooled from 760°C.
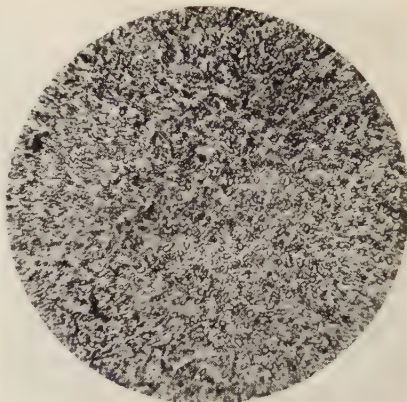
FIG. 17.—*N*84-2. W.-Q. 760°C., T. 500°C., cooled in furnace.
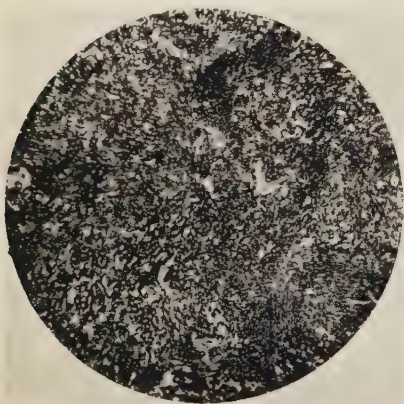
FIG. 18.—*N*105-2. Air-cooled from 760°C.
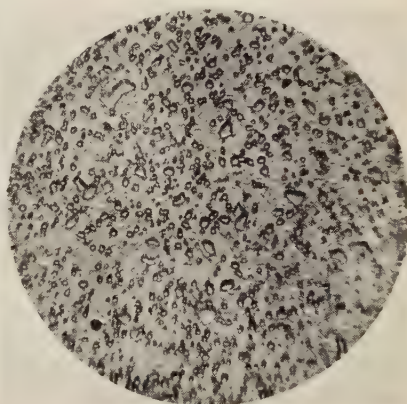
FIG. 19.—*N*105-4. W.-Q. 760°C., T. 680°C., cooled in furnace.
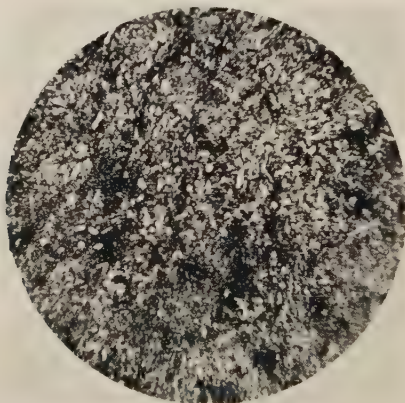
FIG. 20.—*N*105-5. W.-Q. 760°C., T. 500°C., cooled in furnace.

W.-Q.=water-quenched ; T.=tempered.
NOTE : All the above temperings were of 2 hr. duration.

fractures and microstructures are shown in Figs. 5 and 6 (Plate XXVIII.), and 14 and 15 (Plate XXX.).

Steel N84.—A small ingot of this steel was forged into a round bar 30 mm. in diam. and 200 mm. in length, in order to obtain the impact and tensile test-pieces of the dimensions shown in Fig. 1, *B.* Table VI. records the treatment given and the results obtained. In Figs. 7 (Plate XXIX.), and 16 and 17 (Plate XXXI.), are shown the fractures and microstructures of some of the test-pieces.

TABLE VI.—*N84. Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress. Kg. per sq. mm.	Elastic Limit. Kg. per sq. mm.	Elongation. %	Reduction of Area. %	Brinell Hardness Number.	Impact Value. Kg.-m. per sq. cm.
N84–1	Air-cooled from 760° C.	82·0	42·0	15·3	22·0	217	2·66
N84–2	W.-Q. 760° C., T. 500° C. for 2 hr. ; cooled in furnace	104·0	92·0	12·55	18·0	293	4·0

W.-Q. = water-quenched ; T. = tempered.

The impact test-piece N84–2 was cracked after quenching; the crack is shown in Fig. 7, II. The impact resistance, however, is higher than that of test-piece N84–1.

Steel N105.—A bar 100 mm. square and 380 mm. in length was forged to make the test-pieces. With this steel it was much more difficult to obtain the desired results, both for greater impact resistance and higher tensile strength. Table VII. gives details of the treatment applied and the results obtained. Fractures and microstructures of impact test-pieces of some of the specimens are shown in Figs. 8 to 10 (Plate XXIX.), and 18 to 20 (Plate XXXI.).

Summary.—On tempering quenched steel a finely granular pearlite is obtained, which gives to the steel both a tensile strength and an impact resistance greater than that given by laminar pearlite in annealed steel.

The tempering temperature must be sufficiently low, though it must be above the temperature at which Hallimond's " labile

shower " would occur. For low-carbon steels a temperature of 500° C. appears to be the best. For higher percentages of carbon the temperature of 580° C. has yielded very good results.

TABLE VII.—N105. *Treatment and Mechanical Properties.*

Specimen No.	Treatment.	Maximum Tensile Stress. Kg. per sq. mm.	Elastic Limit. Kg. per sq. mm.	Elongation. %	Reduction of Area. %	Brinell Hardness Number.	Impact Value. Kg.-m. per sq. cm.	Fatigue Limit. Kg. per sq. mm.
N105–1	Air-cooled from	76·0	40·0	10·0	40·0	241	5·5	± 45
N105–2	760° C.	70·0	34·0	14·0	44·6	250	3·0	± 49
N105–3	W.-Q. 760° C., T. 680° C. for	68·0	37·0	19·0	51·6	226	7·7	± 32
N105–4	2 hr.; cooled in furnace	68·5	41·0	20·0	45·0	219	7·3	± 36
N105–5	W.-Q. 760° C., T. 500° C. for	107·0	94·0	5·5	28·0	342	2·8	± 73
N105–6	2 hr.; cooled in furnace	92·0	...	...	12·7	340	3·2	...
N105–7	W.-Q. 760° C., T. 580° C. for 2 hr.; cooled in furnace	83·5	55·0	19·2	54·0	259	6·4	...
N105–8	W.-Q. 760° C., T. 580° C. for 2 hr.; air-cooled	83·5	81·0	13·5	36·0	265	6·1	...

W.-Q. = water-quenched ; T. = tempered.

If the 0·84 per cent. carbon steel had been tempered at 580° C., the impact resistance might possibly have been increased without diminishing the tensile strength ; at any rate, the tensile strength would not have been inferior to that of the normalised steel.

In conclusion, it is a great pleasure to the author to renew the assurance of his gratitude to the Sociedad Española de Construcción Naval for their assistance in furnishing him with several samples of carbon steel of various percentages. The behaviour of these steels has been highly satisfactory, not only for their mechanical properties, but also for the toughness exhibited under every treatment to which they have been submitted.

DISCUSSION.

Professor CARL BENEDICKS (Stockholm), in opening the discussion, mentioned that Fig. 19 (Plate XXXI.) in the paper gave precisely the structure of the steel to which he had referred in his previous remarks on Messrs. Herrero and de Zubiria's paper. Further, he thought it was extremely useful to go, as the author did, into details regarding the thermal treatment of steel. Just previous to leaving Stockholm he had discussed with Professor Johansson—well known to the members of the Institute—the fact that the great Swedish metallurgist, Brinell, had considered that a carbon steel containing 0·9 per cent. of carbon was of no considerable practical use. According to Brinell, it was preferable to use a steel containing less carbon—say 0·7 or 0·8 per cent.— or more carbon—say 1 per cent. ; other metallurgists probably had come to the same conclusions. Now, as a matter of fact, the critical transformations of a 0·9 per cent. carbon steel were well known nowadays to be restricted to a temperature lower than that for other carbon steels. That signified that a given steel-treating temperature might be considered to be comparatively higher for a 0·9 per cent. carbon steel than for other steels. Hence, it appeared plausible that the thermal treatment of a 0·9 per cent. carbon steel must be carried out in a more delicate way than for other steels, and that might be the reason why the 0·9 per cent. carbon steel was avoided at a time when delicate temperature control was much more difficult than now. Thus, even if in older days Spain, and also—he was proud to say— Sweden, had produced excellent qualities of steel, it was necessary nowadays, in order to guarantee the very highest qualities, to enter upon the details of thermal treatment—as was done in the present paper.

A very interesting result was that given in Table II. for the steel $B15$ (0·155 per cent. carbon) : the specimens (1 and 2) air-cooled from 880° C. gave the impact values 22·6 and 14·0, while the quenched specimens (3 and 4) annealed for 2 hr. at 750° C. each gave only the value 1·5. The author apparently attributed that strong decrease to a recrystallisation of the ferrite, occurring between 500° and 750° C. A considerable grain-growth, of course, might cause a strong decrease of the impact values. However, he (Professor Benedicks) found difficulties in assuming that a reheating during 2 hr. at a temperature scarcely more than about 30° above Ac_1 should be able to produce a considerable grain-growth. Hence, some additional explanation seemed desirable. Now, the specimens 3 and 4 might be considered to be well annealed, and must present plain, well-developed grain boundaries, which might be followed, at least partly, by the fractures on impact. In the specimens 1 and 2, on the contrary, the grain boundaries were probably not so well developed. In a similar

way, in specimens 3 and 4, scarcely any effect of cold-working should occur; on the contrary, in specimens 1 and 2 previous cold-work might not be entirely eliminated, or might even arise from some deformation occurring during the comparatively rapid air-cooling.

It would be extremely interesting to know whether that brittleness, caused by the annealing at 750° C. followed by slow cooling, would not be eliminated if the steel were subjected to some cold-working. That, of course, would be explained likewise by the author's supposition of a coarse recrystallisation structure in specimens 3 and 4. Anyhow, that point was very interesting, and merited further examination; any analogy seemed scarcely known, except in the case of a chrome-nickel steel.

Mr. ORLAND wrote in reply that he was much pleased to find that the results of his work were considered to have some utility. He thanked Professor Benedicks for his remarks, especially those referring to the phenomenon observed in specimens $B15$–3 and $B15$–4 compared with what was noted in specimens $B15$–1 and $B15$–2. In attributing the great diminution of the impact values of specimens 3 and 4 to a recrystallisation of the ferrite in a coarse grain, he was led to do so by the fact that that constituent commenced to recrystallise in steels of low carbon content at temperatures considerably below the Ac_1 point, round about 500° C. That was, a heating for 2 hr. at 750° C., followed by a cooling in the furnace, implied a heating for over 2 hr. at a temperature 200° above that of recrystallisation. It was true, as Professor Benedicks had said, that heating for 2 hr. at a temperature only 30° above Ac_1 would not bring about any considerable grain increase. But he (the author) believed that that referred to the solid solution formed after passing the Ac_1 point, and the quantity of that solid solution was, as a matter of fact, very small compared with the free ferrite existing in a steel of 0·155 per cent. carbon at 750° C.

Nevertheless, he did not wish to urge the acceptance of his explanation of the curious phenomenon of the great brittleness in specimens 3 and 4. He had not studied those points in his experiments, because what he was principally aiming at was to find a treatment which would give a steel of greater toughness and resistance to impact than a normalised steel. Still, the great brittleness of specimens 3 and 4 formed an interesting case, which called for a more complete study. He would resume his work in the light of Professor Benedicks' remarks, which he would bear in mind in submitting a steel of class $B15$ to new tests.

THE INFLUENCE OF VARYING STRAINS AND ANNEALING TEMPERATURES ON THE GROWTH OF FERRITE CRYSTALS IN MILD STEEL.*

By Professor C. A. EDWARDS, D.Sc.,

AND

TAKETO YOKOYAMA, M.Eng. (Tôhoku), M.Sc. (Wales)
(University College, Swansea).

Introduction.

MANY years ago, Dr. Stead [1] described a peculiar kind of brittleness which he had observed in mild steel sheets. This brittleness took the form of fracture, being easily produced at an angle of 45° to the direction of rolling, and was shown to be associated with a coarsely crystalline structure in the metal.

Later, Chappell [2] and others have shown that when mild steel is cold-worked to the extent that is brought about by a tensile load of from 15 to 18·6 tons per sq. in., subsequent annealing will cause an extraordinary increase in the size of the ferrite crystals within the metal. In one example of a mild steel stamping, which had failed in the course of manufacture, Edwards and Pfeil [3] found it to contain extremely large crystals of ferrite, with more or less continuous bands of cementite at the grain boundaries. In the light of the evidence since obtained, the authors are of the opinion that this particular instance of crystal growth was more directly due to decarburisation during annealing, rather than to straining followed by annealing under conditions that would not produce loss of carbon from the steel.

The object of the present investigation was to make a detailed examination of the influence of varying degrees of cold-work, annealing temperatures, and annealing times, upon grain-growth and other changes of structure in mild steel, and thus endeavour to throw more light upon the problem referred to above.

As a result of the work of previous investigators, some of the variables which are known to influence the growth of ferrite crystals in mild steel may be briefly summarised as follows :

(1) It is known that the presence of certain impurities, in some instances in the dissolved and in others in the undissolved state, plays an important rôle in affecting the extent to which grain-growth will occur, but very much more is required to be known concerning this aspect of the problem.   Jeffries [4] and Smithells [5] have studied the question of grain-growth in tungsten in this connection, more particularly with regard to the effects of un-dissolved impurities.   In their work on the production of large crystals of ferrite in decarburised mild steel, Edwards and Pfeil [3] found that the presence of quite small quantities of undissolved carbide of iron prevents the growth of such large crystals of ferrite on straining followed by annealing, as compared with what would be formed in the absence of such free carbide.   They were also led to believe that the presence of small variations in the amount of carbon dissolved in the ferrite has an important influence in this connection.

(2) Carpenter and Elam,[6] in their work dealing with the production of large crystals in aluminium, found that the initial crystal size of the metal, prior to straining and annealing, was a matter of considerable importance, and, in order to produce single crystals of aluminium, the most suitable initial grain-size was about 36 grains per sq. mm.   With this in view, they found it necessary to anneal their rolled sheets, and thus obtain new equiaxed crystals of approximately uniform size.

In their work on decarburised mild steel, Edwards and Pfeil [7] also found that the grain-size was an important factor, and they indicate that the larger the grain-size the greater is the strain necessary with subsequent annealing to cause the maximum degree of grain-growth on the one hand, or complete recrystallisa-tion on the other.   They also point out that the largest crystals were made from material possessing an intermediate initial grain-size.   The most suitable grain-size for the production of very large crystals of ferrite was found to correspond approximately with 120 grains per sq. mm.

(3) The degree of cold-work before the annealing operation is an important factor governing the degree of grain-growth, and slight variations of permanent strain have very marked effects.

Edwards and Pfeil [7] mention that a critical degree of strain was required to produce single crystals of iron, and less strain than the critical amount was apparently removed on annealing without crystal growth taking place. The greater the strain above the critical amount, the smaller are the grains that are ultimately obtained after annealing. Further, they give evidence which demonstrates that the nature of the strain has an effect on the growth. For example, in the case of specimens that were strained by tension, the outside surfaces of large crystals were always covered by a film of very small crystals (one crystal deep), but specimens strained by rolling were comparatively free from such small surface crystals.

It was also shown by Chappell [2] that plastic deformation applied at any temperature below 900° C. would cause the formation of abnormally large crystals on annealing.

(4) There is no doubt that the temperature and the period of annealing have an influence upon the results obtained ; but, up to the present, little quantitative evidence has been published in this connection. Edwards and Pfeil, [7] in their work on decarburised mild steel, found that the largest crystals were produced by annealing the strained metal in hydrogen at as high a temperature as possible, without reaching the A_3 point, for 72 hr. Chappell [2] states that crystal growth of suitably deformed iron was extremely rapid at 850° to 870° C. Neither the rate of heating nor the rate of cooling appears to have much influence upon grain-growth.

PRESENT INVESTIGATION.

Extensive experiments have been made with sheet steel 1·4 mm. thick, and with $\frac{1}{2}$-in. round bars. The composition of the former material was as follows :

		Per cent.
Carbon	. . . . . .	0·10
Silicon	. . . . . .	Trace
Manganese	. . . . . .	0·33
Sulphur	. . . . . .	0·073
Phosphorus	. . . . .	0·040

In reviewing the whole of the evidence obtained, the authors feel it is not necessary to give more than a very brief summary of the work done on sheets. The chief reason for this is the uncertainty that arises, owing to the difficulty of controlling one

or two disturbing factors which are inevitably associated with
steel in that form. For example, there is always a considerable
variation in the chemical composition, particularly as regards
the carbon content. Although the original ingots may be satis-
factory in this respect, there is always a tendency for the carbon
content to decrease at and immediately below the surfaces, as
a result of oxidation during hot-rolling ; and there is also the
difficulty of preventing further carbon loss during the annealing
of the strained specimens. From the results, which are described
later, it will be evident that all these variables have important
effects upon the results, but they are substantially minimised
when the material is in bar form. In view of this, only the salient
features of the results obtained when using sheet steel are given ;
they are put into a condensed form in Table I.

TABLE I.—*Experimental Results with Sheet Steel Specimens.*

Annealing Temperature. ° C.	Length of Time. Hr.	Degree of Strain showing Signs of Growth. %	Degree of Strain which gave Largest Grain-Growth. %
575	24	10·7	17·5
625	24	10·7	12·4
675	24	8·3	8·9
700	24	7·3	8·0
725	24	6·1	7·8
700 Reannealed 725	24 ⎱ 24 ⎰	6·7	8·0
700	5 days	6·0	7·4

Experiments with Low-Carbon Steel Bars.—Owing to the
disturbing factors already mentioned, as well as the difficulty of
obtaining perfectly even strains in the experimental sheet samples,
and the relatively large surface in proportion to the mass that
must be exposed to the furnace atmosphere, it was thought that
more accurate data could be obtained by the use of bars. For
this purpose, ½-in. round cold-drawn steel was used, which had
the following composition :

		Per cent.
Carbon	. . . . . .	0·08
Silicon	. . . . . .	Trace
Manganese	. . . . . .	0·30
Sulphur	. . . . . .	0·032
Phosphorus	. . . . . .	0·018

All the material was first normalised by being heated at 950° C. for $\frac{1}{2}$ hr. in an atmosphere of coal-gas.   The reason for normalising in an atmosphere of coal-gas will be discussed more fully later, and at this stage all that need be said is that the primary object was to prevent loss of carbon.

In the normalised state the tensile properties of the material were as follows :

Yield stress	12·05 tons per sq. in.
Ultimate breaking stress . . .	19·95 ,, ,, ,,
Elongation on 2 in.	52·0 per cent.
General elongation excluding fracture	38·5 ,,

The microstructure of the steel in the normalised condition is shown in Fig. 5 (Plate XXXII.).

At this stage it should be noted that, on examining cross-sections under the microscope, it was found that the carbon was not perfectly uniform throughout, the outer portions containing somewhat less than the centre.   It was further observed that there was a tendency for the ferrite crystals in the outer parts to have thin films of cementite at their boundaries.

Oxidation during Annealing after Straining.—One of the most difficult problems encountered in this work was the prevention, or even the control, of the degree of oxidation, or decarburisation, during annealing.   This is liable to occur at all but the lowest temperatures, and its extent increases as the temperature is raised and the period of annealing is extended.

The following methods of procedure have been used in attempting to overcome this difficulty :

(*a*) By filling the furnace with oxygen-free nitrogen dried by passing it through concentrated sulphuric acid.

(*b*) By using an atmosphere of coal-gas, especially when the annealing temperature required was comparatively low.

(*c*) By carefully protecting the specimens, by placing them in a number of wrappings of thin steel sheet, and using an atmosphere of coal-gas.   This method gave the most satisfactory results.

There is another possible oxidation difficulty, though of a somewhat different kind (the effects of which cannot at present be estimated), arising from the oxygen content of the steel itself. At high temperatures, when the annealing periods are prolonged,

the authors believe this oxygen reacts with the carbon in the steel, and thus tends to cause a reduction in the carbon content. Decarburisation of this kind might cause crystal growth.

After normalising, bars were strained from 4 to 14 per cent. elongation, in steps of $0 \cdot 5$ to $1 \cdot 0$ per cent., in a 10-ton Buckton universal testing machine. After straining to the required degree, the portions of the bars well away from the gripped ends were cut into pieces 1 in. long. One of these samples, corresponding with each degree of strain, was used for each annealing tempera- ture. A group of samples of this kind constituted a series, which, after being carefully wrapped in thin sheet metal, was annealed in an atmosphere of coal-gas at distinct temperatures, ranging from $600°$ to $920°$ C., for periods varying from 2 hr. to 7 days. It should be mentioned that the stream of coal-gas was not flowing through the furnace during the heat treatment, and therefore the amount of carburisation which took place was negligible, being confined, when it occurred, merely to a superficial layer or film. Each sample was then cut into two $\frac{1}{2}$-in. pieces, one being used for an examination of the microstructure of the cross-section of the bar, whilst the other was cut into two, parallel with the direction of rolling, in order to examine the structure in that direction.

Regulation of Furnace Treatment.—The temperature of the furnace was kept practically constant by means of a Cambridge thermo-electric thermostat. As a check against the efficiency of the thermostat, the temperature of the furnace was constantly taken by means of a thread recorder. The thermocouple for the temperature recorder was placed as nearly as possible in the centre of the specimens, while that controlling the thermostat was placed near the wall of the furnace.

Experimental Series A.—For these experiments the annealing temperature was $600°$ C., and the time 24 hr.

The specimen which showed the largest crystals was that which had been strained 8 per cent., though the crystals in the sample strained 7 per cent. were not very much smaller. The crystals in those specimens strained less than 7 per cent. showed no signs of growth. A typical microstructure of the sample strained 8 per cent. is shown in Fig. 6 ; and, for comparison, the structure of a sample which had been subjected to exactly the

same heat treatment, but which had not been strained, is repro-
duced in Fig. 7. It will be noticed that the ferrite crystals in
Fig. 6 are extraordinarily irregular in shape, and show practically
no sign of being equiaxed. The carbon was in the granular
pearlitic form in all cases. The effects of varying degrees of
strain can be more easily recognised from the series of low-power
micrographs, Figs. 8 to 11, which show the complete cross-section
of each specimen.

Series D.—In this series of tests, in which the annealing
temperature was 675° C., and the period 24 hr., there is no doubt
that the specimen strained 6 per cent. shows the largest crystals
(Figs. 12 to 14, Plate XXXIII.).

The specimen strained 4 per cent. did not show any crystal
growth in the central parts, but there were medium large crystals
of a somewhat columnar kind in the outer rim. Crystal growth
can be seen to have taken place throughout the specimens strained
5, 6, and 7 per cent., with a slight tendency for it to be more
marked towards the outside edge ; but, in each instance, they
are virtually equiaxed. The greater the strain above 6 per
cent., the smaller were the crystals produced by annealing.
Within this range of straining, that is, from 4 to 8 per cent.,
there were no indications of columnar crystals at the outside
edge, but in the specimens strained 9 per cent. there were quite
large columnar crystals near the edge.

It may be pointed out that it was often found that when
columnar crystals developed at the outer edges of the specimen
no crystal growth could be detected in the central parts ; if crystal
growth took place in the centre, the crystals at the edge were not
columnar, even though they were often rather larger than those
present in the centre. These larger crystals are in some way
associated with the lower carbon content at and near the edge of
the specimen. When the annealing temperature was raised, the
amount of strain necessary before specimens developed columnar
crystals was greater, and, under these conditions, the size of the
columnar crystals obtained was larger. This will be discussed
in greater detail later.

Series B.—The annealing temperature for these experiments
was 700° C., and the time 24 hr. The pearlite was, in most cases,
found to be of the divorced type, and in some instances there

were definite indications that it had become spheroidised.   The
specimen which had been strained 6 per cent. contained the largest
ferrite crystals.   Specimens strained 4 and 5 per cent. gave large
columnar crystals at the edge, but no crystal growth in the central
portions, whilst samples strained 6 and 7 per cent. gave slightly
larger crystals at the rim than in the middle.   Figs. 15 and 16
show the microstructures of an unstrained sample, and that of
the specimen strained 6 per cent., after each had been annealed at
700° C. ; Fig. 17 is a low-power micrograph of the latter specimen.

   Series C.—The annealing temperature was 725° C., and the
period 24 hr.   It was evident from the microstructures that the
annealing temperature was a little higher than the A_1 change
point.   Specimens strained 4 and 5 per cent. showed large crystals,
the former being somewhat larger than the latter.   Low-power
micrographs of specimens strained 3, 4, and 5 per cent. are shown
in Figs. 18, 19, and 20 (Plate XXXIV.).   Figs. 21, 22, and 23
are micrographs of a specimen unstrained previous to annealing,
and of others strained 4 and 7 per cent. respectively.

   Influence of Temperatures above 725° C.—A large number of
experiments were made by annealing at temperatures between
730° C. and 890° C. for varying times, of which the following is
a summary of the main features, more especially in regard to
those relating to the 24-hr. period of annealing.   This period
was selected, not because it shows any special points which are
fundamentally different from those of other experiments, but
merely to make it more easily comparable with those already
discussed.   The relationship between these annealing tempera-
tures, degree of strain, and crystal growth are put in tabular form
below :

Annealing Temperatures. ° C.	Strain producing Maximum Growth. %
730	5
760	6
850 to 890	7

   All the results from these experiments show that they are
unlike those for annealing temperatures below 730° C., inasmuch
as the amount of strain required to give the largest crystals had

to be increased as the annealing temperature was raised above 730° C., whereas the reverse was the case for temperatures below 730° C. It should, however, be noted that the crystals obtained by annealing at temperatures above A_1 were not so large as those produced by annealing critically strained samples below the A_1 point. After annealing at temperatures just above the A_1 change, there was a distinct tendency for the pearlite to become located at the boundaries of the ferrite; this is very clearly illustrated in Figs. 24 and 25 (Plate XXXV.).

With higher temperatures the pearlite appeared to be almost evenly distributed throughout, though there seemed to be indications that the ferrite boundaries passed through the large areas of pearlite. The microstructures of the specimens annealed at from 860° C. to 890° C. showed a mixture of large and small crystals.

SUMMARY OF RESULTS OBTAINED WITH SOFT STEEL BARS.

Broadly speaking, it may be stated that the essential features of the results obtained with soft steel bars were very similar to those of the mild steel sheets.

(1) The critical strains for the various annealing temperatures were as follows :

Annealing Temperatures. ° C.	Critical Strain for Maximum Growth. %
500	10 (estimated)
600	8
675	6
700	5
725	4

The higher the annealing temperature, provided the straining corresponded with the critical degree, the larger were the crystals, but they took a longer time to grow. The higher the annealing temperature, &c., the more sensitive was the material to small variations of strain; in other words, the more necessary it was to strain to the correct extent in order to produce the largest crystals.

(2) Strains less than the critical amounts followed by anneal-ing did not cause crystal growth.   As the degree of straining was increased above the critical amount the smaller were the crystals that were grown.   Very severe strains caused recrystallisation.

Fig. 1 illustrates the chief characteristics concerning crystal growth, caused by annealing specimens strained in tension on the one hand (Curve I.), and steel sheets strained by rolling on the other (Curve II.).   The point C corresponds with the
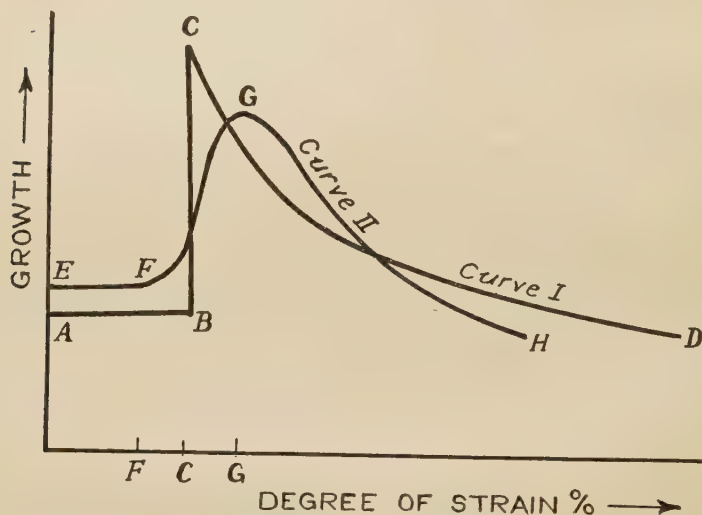
Fig. 1.

critical degree of strain, giving the maximum amount of crystal growth.   Straining within the range AB gave no growth, whilst the amount of growth which took place after straining within the limits CD decreased as the degree of straining increased.; the strain-growth curve over this range is hyperbolic.

Strains produced by purely tensional stresses are no doubt comparatively evenly distributed throughout the cross-section, and also along the length of the bar, except, perhaps, when the strains are less than about 4 per cent. elongation.

In cold-rolling the strains are not so uniform throughout the thickness of the sheet, being greater near the surfaces than in the centre.   It is no doubt because of this that the character

of the curve illustrating crystal growth after rolling is not exactly the same as that for tensional strains.

EF, Curve II., represents the range of strain over which no crystal growth occurred. The point *F*, at which growth became evident, represents less strain than *C*. The degree of growth increased with the degree of strain from *F* to *G*. The amount of strain needed to produce the largest crystals by rolling and annealing was greater than with tensional strains; but the size of the crystals obtained by the former treatment, represented by *G*, was not so large as by the latter, namely, point *C*.

The section of the curve *GH* is similar to, though somewhat steeper than, curve *CD*. This merely means that, when the amount of strain produced by tension is expressed as " elongation per cent.," and the strain given by cold-rolling is expressed as " percentage reduction in thickness," recrystallisation of the rolled specimens takes place at a lower strain value.

(3) The crystals obtained in the steel bars, after straining the critical amount and annealing at the appropriate temperature, were larger than those in a sheet strained the critical amount and annealed at the same temperature.

(4) The longer the period of annealing and the higher the temperature up to the A_1 point, the larger were the ferrite crystals formed.

(5) Other things being equal, the higher the temperature above the A_1 point, the smaller were the crystals produced.

It is interesting and significant to plot the critical strains producing the maximum degree of crystal growth at annealing temperatures below 730° C. against the corresponding annealing temperatures (see Fig. 2). From this diagram it appears that the critical strain required is a linear function of the temperature. It is well known from the work of Edwards and Pfeil [7] that, when dealing with decarburised steel and using much higher temperatures than 730° C., the critical strain required to produce very large ferrite crystals must be considerably less than 4 per cent., which was the strain that gave the largest crystals on annealing at 725° C. Attention is drawn to this merely to indicate that there is some justification for extending the curve in Fig. 2 as a straight line to meet the A_3 critical change point. Looked at from this point of view, it would seem that pure iron should be

extraordinarily sensitive to small strains in regard to the growth
of large crystals when at temperatures immediately below the
A_3 change.

Fig. 3 shows the relationship between the size of the crystals
in specimens which had been strained to the critical degree and
the corresponding annealing temperatures.   Up to the A_1 change
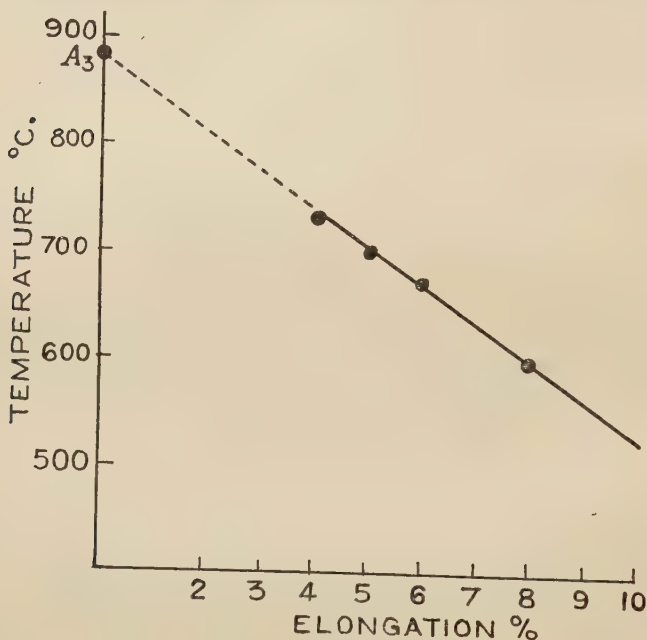
Fig. 2.

the size of the crystals produced increased with the annealing
temperature, but above the A_1 change the size of crystal obtained
decreased.   The figures given on the curve between the tempera-
tures A_1 and A_3 are the estimated critical strains for the corre-
sponding temperatures for pure, or decarburised, steel.   The
presence of the carbon has a much more marked effect in pre-
venting crystal growth between temperatures of the A_1 and A_3
changes than it has at temperatures below A_1.

(6) More extended crystal growth took place in the direction
of straining than in the transverse direction ; but whether this

was to some extent due to inequalities of composition or not, the authors are unable to decide.

(7) For the material under discussion, the authors believe they have carefully examined the whole range of temperature within which strained ferrite will grow on annealing, and they also think the same can be said in regard to varying strains, and for all practical purposes to periods of annealing. In spite of this, however, there seems to be a limiting size beyond which the
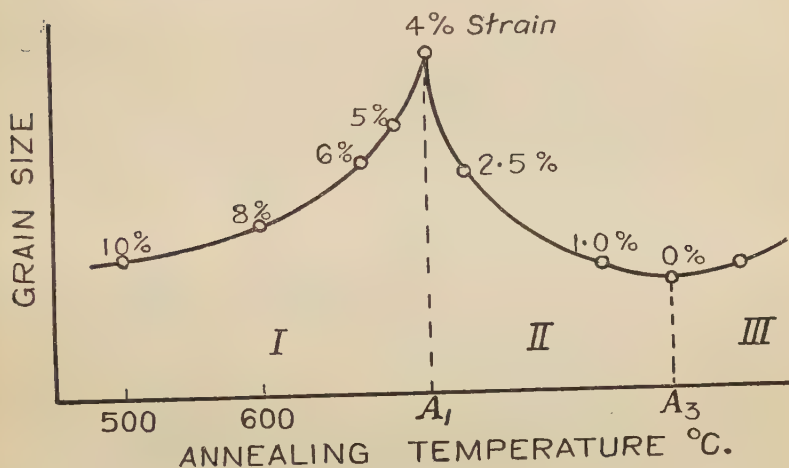
Fig. 3.

ferrite crystals will not grow. It does not seem necessary to give a figure for this limit, especially as micrographs of specimens that gave the largest crystals are illustrated in the paper. At first sight, it may appear rather remarkable that very much larger crystals were not grown, particularly in view of the incomparably larger degree of growth which can be produced by first removing the carbon from the metal. There are, however, numerous factors which contribute to this difference :

(i) The presence of carbon makes it impossible to raise the annealing temperature above the A_1 change without increasing the quantity of a second phase present, and this increases the barriers which tend to prevent growth.

(ii) The work of Edwards and Pfeil [7] has shown that the largest crystals were produced in the absence of carbon by the use of low strains and temperatures approaching A_3. These high temperatures could not be used in the present investigation, and, in consequence, greater strains had to be applied in order to activate the ferrite at the lower temperatures. Hence, smaller crystals must be produced.

(iii) Even at temperatures below A_1 the pearlite, or carbide of iron, would, to some extent, act as a barrier against the ferrite crystal growth.

(iv) The presence of pearlite must give rise to far greater inequalities of strain in the original ferrite crystals, and in this way, whilst some parts are correctly strained for crystal growth, others are so highly strained as to cause recrystallisation.

(8) The character of the carbide of iron, or pearlite, varied according to the treatment received by the specimens ; the following forms were more or less clearly defined within the ranges of treatment mentioned :

(i) The normal pearlite present in the original normalised specimens and in those samples annealed at 600° C.

(ii) Divorced pearlite, or spheroidised cementite, present in samples annealed at 675° and 700° C.

(iii) Pearlite which had migrated to the boundaries of the newly formed ferrite crystals, present in samples annealed at or a little above the A_1 change.

(iv) Massive cementite, frequently found in the form of a horseshoe pattern in samples annealed at about 870° C. after straining.

(9) Decarburisation caused columnar crystals to grow, and the extent of this growth was influenced by varying degrees of strain. This is discussed in greater detail in Appendix II.

APPENDIX I.

INFLUENCE OF SLOW HEATING.

It was thought desirable to determine whether the rate of heating to any particular annealing temperature would have

A. *Asbestos*
B. *Rubber Cushion*
C. *Crucible to prevent Surface Tension and Oxidation effects*
E. *Bar Clamp to prevent Resistance Tube K from Floating*
F. *Furnace*
G. *Glass Tube*
H. *Mercury Reservoir*
J. *Fine Jet*
K. *Silica Resistance Tube*
MR. *Main Resistance*
R. *Resistance Winding*
S. *Stand*
T. *Mercury Tube*
V. *Main Tap*
W. *Water-Cooling*
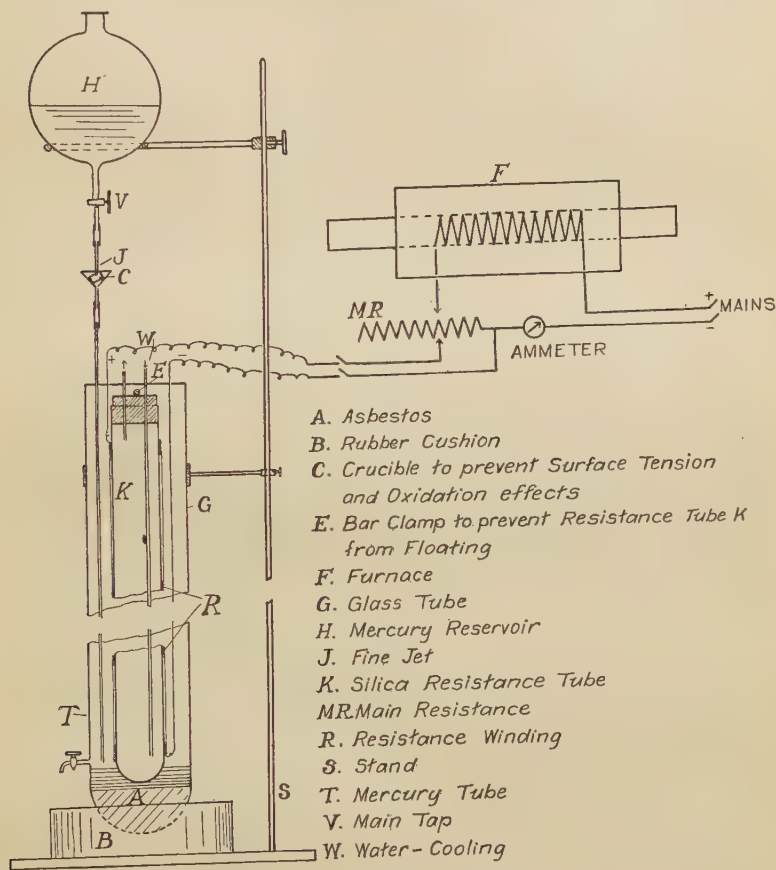
FIG. 4.—Variable Resistance.

much, if any, influence upon the extent to which crystal growth would develop. A sketch of a convenient apparatus that would enable the rate of heating to be steady, progressive, and under control is shown in Fig. 4. (K) is a silica tube, closed at one end,

$1\frac{1}{2}$ in. in diameter and 18 in. long.   This was wound with 135 yards
of nichrome resistance wire (R) $(4\cdot29$ ohms per yard).   This
resistance, about 660 ohms, was connected in parallel with the
main resistance (MR) controlling the furnace (F), which had a
resistance of about 43 ohms.   The resistance (R) was placed in
a glass tube (G), $1\frac{3}{4}$ in. in diameter and 24 in. long, the bottom
of which was closed by an asbestos bung (A) resting on a rubber
cushion (B) and supported in the stand (S).   A fine glass jet (J)
was connected to a mercury reservoir (H) for the supply of small
drops of mercury to the glass tube (G).   The higher the mercury
level in the tube, the less was the resistance, and the greater was
the current passing through the furnace.   The desired rate of
heating was obtained by adjusting the orifice of the glass jet and
the main tap (V) of the mercury reservoir.   The silica tube was
cooled by internal water circulation (W).   Difficulties were at first
encountered, due partly to oxidation of the impurities in the
fine drops of mercury, and partly to surface tension effects ; but
these were eliminated by dipping the supply jet of mercury into
a pool of mercury in the small crucible (C), from which it over-
flowed into the apparatus.   The drops of mercury passed down
the fine silica tube (T) to the bottom of the apparatus, the object
being to remove any risk of irregular short-circuiting. (E) is
a bar-clamp to prevent the resistance tube from floating.

With the aid of this apparatus the following experiments
were made :

Specimen Mark.	Temperature. ° C.		Heating-up Period. Days.
	From—	To—	
J	600	690	2
S	690	725	3
T	500	715	7

In all cases the specimens were prepared in the usual manner,
that is, normalised in an atmosphere of coal-gas and then strained.

Experiment J.—The largest degree of crystal growth took
place in the specimen strained 7 per cent., and the greater the
strain above this limit, the smaller were the final crystals obtained.
A few crystals grew in the specimen strained 6 per cent., but no

growth took place in any of the specimens strained less than 6 per cent. The crystal growth was very even and of an equiaxed character for the 7 per cent. strain—see Fig. 26 (Plate XXXV.)— but there were still indications that some small crystals remained unabsorbed. These results do not differ very much from those given in series *A* and *D* ; indeed, it is highly probable that if the other variables, namely, the maximum temperature and the total length of time at that temperature, had been the same, the strains giving the largest crystals would also have been similar :

Specimen Mark.	Highest Temperature. ° C.	Period. Hr.	Strain for Largest Crystals. %
A	600	24	8
D	675	24	6
J	600 to 690	48	7

Experiment S.—The object of this experiment was to determine the effect of slow heating up to the A_1 point on crystal growth. Specimens which had been heated slowly up to 690° C. from 600° C. in two days were again heated slowly from 690° to 725° C. in 24 hr. The crystals which had grown by the previous annealing did not grow much larger ; but small crystals, which had not been absorbed during the first annealing, were absorbed by this further treatment. The highest temperature, 725° C., was somewhat higher than the A_1 point ; it is possible that this is the reason why growth did not take place as a result of this treatment in specimens strained less than 7 per cent.

Experiment T.—The object of this experiment was to examine the effect of still slower heating than that in experiment *J*, up to a temperature just below the A_1 point. In this case, the heating from 500° to 715° C. took 7 days. The largest crystals were found in the specimens strained 6 per cent. (see Figs. 27 and 28, Plate XXXV.). The crystal size was nearly the same as that in the specimen strained 4 per cent. and annealed at 725° C. for 24 hr.

Another experiment consisted of heating specimens of the usual kind at 675° C. for 48 hr., and then heating again at 700° C. for 24 hr. One interesting feature was observed, namely, that large crystals developed during the second annealing in the

specimen strained 5 per cent., which showed no trace of such crystals after the first annealing. Hence, though perhaps a substantial proportion of the hardening due to cold-work was removed by the prolonged annealing at 675° C., the particular kind of strain that gives rise to crystal growth still remained in the specimen.

The above experiments seem to show that quite wide differences in the rate of heating to any specified temperature do not have a very material effect upon the final results.

APPENDIX II.

Effects of Decarburisation during Annealing, &c.

During the early experiments made with the bar material it was frequently observed that if columnar crystals were found to have developed in the outer parts of the specimens no growth could be detected in the central portions, even when the conditions of treatment as regards straining, &c., were such that growth might otherwise be expected in the centre. Further, when growth took place in the centre, though the crystals towards the outer surfaces were larger, they were not columnar in appearance. This larger size of the crystals at the outer parts was, no doubt, due to the lower carbon content in those areas prior to the straining of the specimens, and not to the loss of carbon during the experimental annealing. There was every reason to suppose, on the other hand, that the appearance of columnar crystals (such as those referred to above) was in some way associated with decarburisation during the annealing of the strained specimens. When the annealing temperature was raised it was found that the amount of strain necessary before specimens developed this columnar type of crystals was higher; but the size of columnar crystals formed was larger.

Stead [8] observed this columnarisation of the ferrite crystals on heating steel in lime for a few hours at temperatures of 700° C. to 800° C., when decarburisation was produced, and he drew the following conclusions :

(a) Carbonless iron has not been made to assume the columnar structure by any simple heat treatment.

(b) If the annealing is conducted in a non-oxidising atmosphere or environment, the peculiar structure is not developed.

(c) It is not affected by the diffusion of carbon from a high-carbon steel to a pure iron, when they are brought in perfect contact and annealed together.

(d) It is only developed when the carbon is removed by oxidising agents from the surface, and when the temperature is below 850° C.

Austin [9] also noticed the same feature when decarburisation took place by annealing in hydrogen, and he put forward an explanation of the columnarisation.

The following two series of experiments throw some light upon the effect of decarburisation upon the critical strain required to produce equiaxed crystal growth. In the first, specimens were heated in a slow stream of coal-gas at 950° C. for 3 hr. to give a thin carburised film on the surface; these bars were strained from 3 to 5 per cent., and were then annealed at 725° C. for 24 hr. in a furnace filled with coal-gas. The sample which had been strained 3 per cent. showed no crystal growth, that strained 4 per cent. gave pronounced growth, whilst the 5 per cent. specimen gave smaller crystals than the 4 per cent.; there was no columnarisation in the outer portions.

In the other experiments, a similar series of strained specimens, but annealed under slightly oxidising conditions, were dealt with; the annealing temperature and time were the same as before. Specimens strained 7 and 8 per cent. showed fairly large crystals in the central parts, whilst specimens strained 4, 5, and 6 per cent. had large columnar crystals on the outside, but no crystal growth in the middle.

In order to determine whether decarburising the specimen after growth had been produced would affect the crystals already produced, or cause columnar crystals to be formed at the outside, a specimen which had been carburised, strained, and annealed for 24 hr. at 725° C. to give large crystals was again annealed for 24 hr. in air. The result of this second treatment showed that the interior crystals were unchanged, except that they had grown a little by the absorption of some of the small crystals. It is therefore safe to conclude that decarburisation does not

affect the crystals in the centre of the specimen once they have grown. Small columnar crystals were found at the rim ; decarburisation had evidently taken place only to a limited extent.

The next tests were designed to demonstrate the effect of decarburising conditions upon the amount of strain necessary to cause polygonal crystals to grow on annealing ; in other words, whether the decarburisation of the surface before annealing, to counteract the influence of carbon loss on annealing, affects the growth. Two kinds of soft steel bar specimens were used : (a) carburised at 950° C. to the extent of about 0·5 mm. depth, and (b) normalised without carburising. Each series was strained from 3 to 5 per cent., and annealed in air at 725° C. for 24 hr. The results with the uncarburised bars indicated that no growth occurred in the centre of any of the specimens, but there were signs of columnar growth in the rim of the specimen strained 3 per cent., thin columnar growth in the specimen strained 4 per cent., and large columnar crystal growth in the specimen strained 5 per cent. (see Figs. 29 and 30, Plate XXXVI.).

With the carburised specimens, no growth took place in the central portions of the 3 and 4 per cent. strained samples, but large growth occurred in the 5 per cent. strained piece, as shown in Fig. 31. The extreme edges of the specimens were decarburised, but the decarburisation and the corresponding columnarisation had penetrated only to a minute depth, owing to the protection afforded by the carbon. These results again show that if columnar crystals are formed to an appreciable extent the strain required for the production of equiaxed crystal growth in the centre of the specimen must be greater.

It may be mentioned that it has been observed throughout this investigation, and by others working in the same laboratory, that whenever columnar crystals are formed and there is still carbon left in the middle of the bars there is always a marked tendency for beaded cementite, or thin films of cementite, or both, to become located at crystal boundaries of the ferrite ; this is illustrated in Fig. 32.

From the experimental evidence obtained in this section of the investigation, the following conclusions may be drawn :

(1) There appears to be no doubt that the growth of columnar crystals at or below 725° C. is due to the combined influence of cold-work and decarburisation.

PLATE XXXII.

FIG. 5.—Structure of bar after normalising at 950°C. for 30 minutes. ×100.

FIG. 6.—Annealed at 600°C. for 24 hours after straining 8 per cent. ×100.
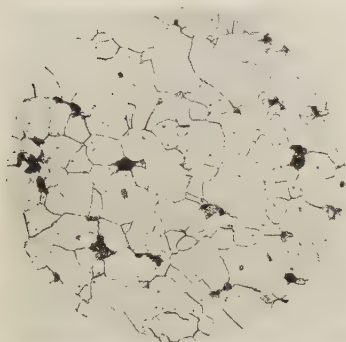
FIG. 7.—Annealed at 600°C. for 24 hours without previous straining. ×100.
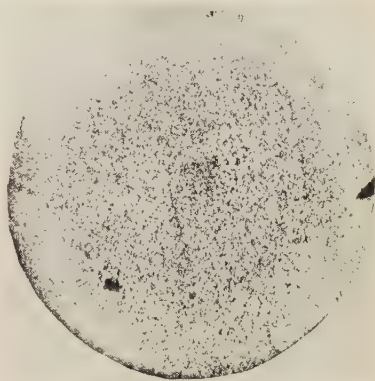
FIG. 8.—Annealed at 600°C. for 24 hours after straining 6 per cent. ×4.
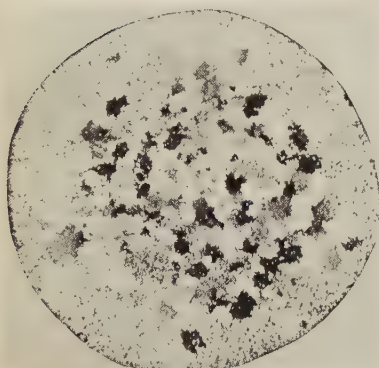
FIG. 9.—Annealed at 600°C. for 24 hours after straining 7 per cent. ×4.
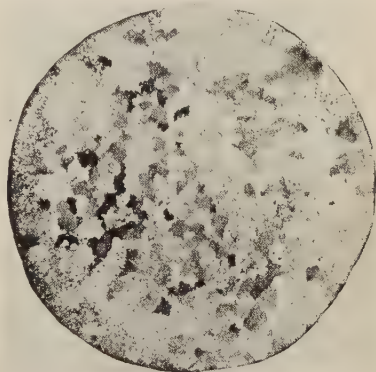
FIG. 10.—Annealed at 600°C. for 24 hours after straining 8 per cent. ×4.

PLATE XXXIII.
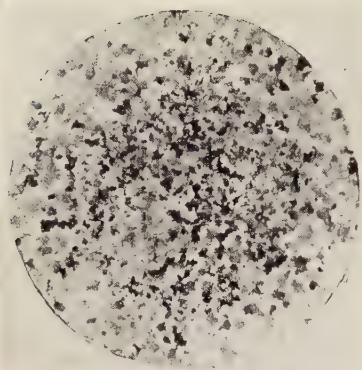
FIG. 11.—Annealed at 600°C. for 24 hours after straining 9 per cent. ×4.
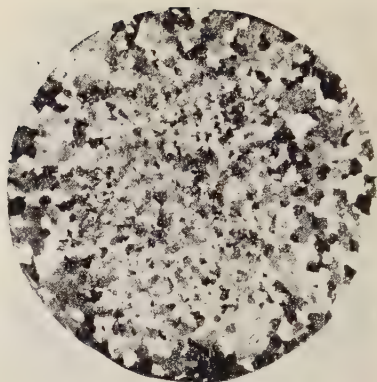
FIG. 12.—Annealed at 675°C. for 24 hours after straining 5 per cent. ×4.
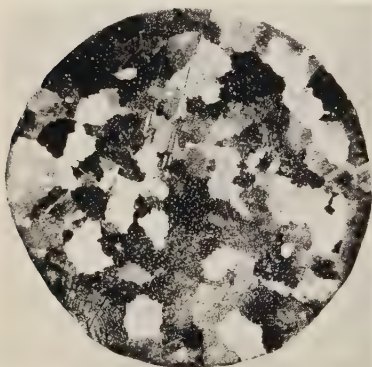
FIG. 13.—Annealed at 675°C. for 24 hours after straining 6 per cent. ×4.
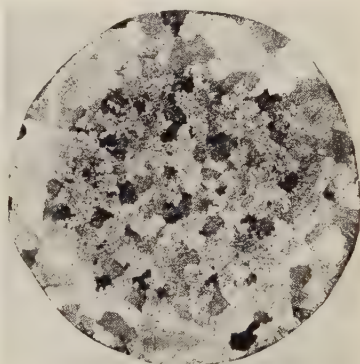
FIG. 14.—Annealed at 675°C. for 24 hours after straining 7 per cent. ×4.
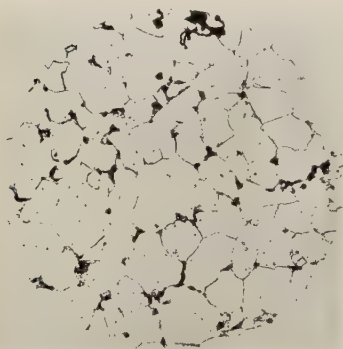
FIG. 15.—Annealed at 700°C. for 24 hours without previous straining. ×100.

FIG. 16.—Annealed at 700°C. for 24 hours; typical structure of samples after straining 5 to 6 per cent. ×100.

PLATE XXXIV.
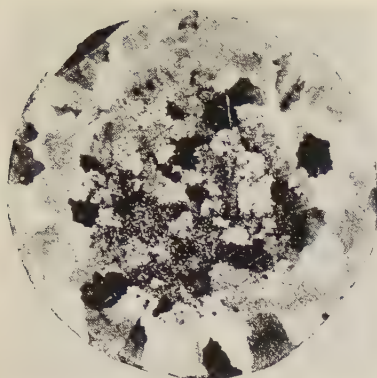
FIG. 17.—Annealed at 700°C. for 24 hours after straining 6 per cent. ×4.
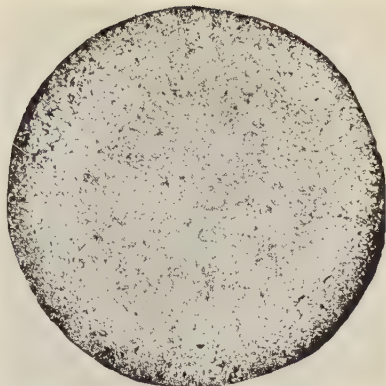
FIG. 18.—Annealed at 725°C. for 24 hours after straining 3 per cent ×4.
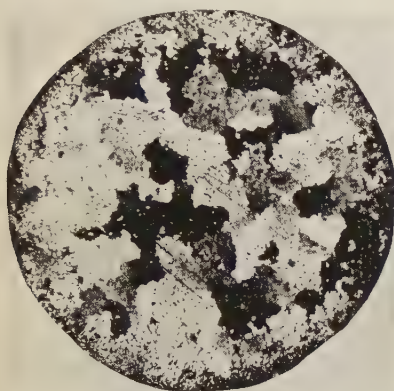
FIG. 19.—Annealed at 725°C. for 24 hours after straining 4 per cent. ×4.
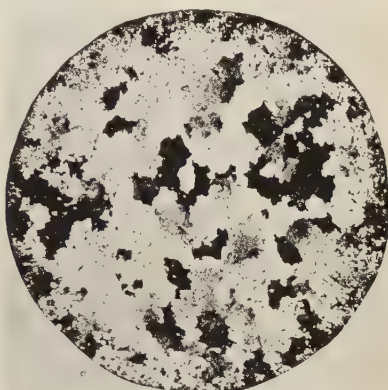
FIG. 20.—Annealed at 725°C. for 24 hours after straining 5 per cent. ×4.
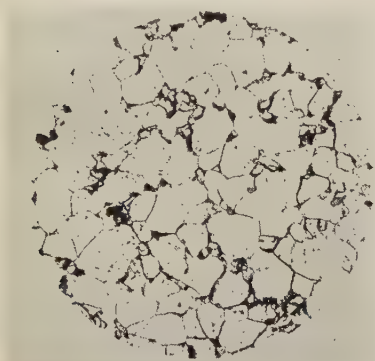
FIG. 21.—Annealed at 725°C. for 24 hours without previous straining. ×100.

FIG. 22.—Annealed at 725°C. for 24 hours after straining 4 per cent. ×100.

PLATE XXXV.

FIG. 23.—Annealed at 725°C. for 24 hours after straining 7 per cent. ×100.
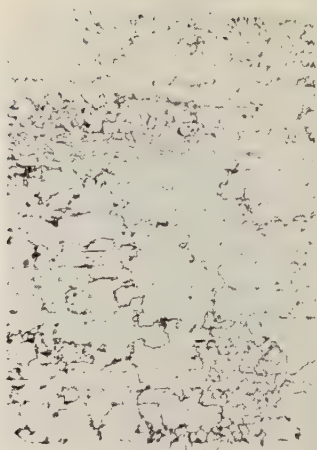
FIG. 24.—Annealed at 725°C. for 24 hours after rolling (reduction 8·3 per cent.). ×50.
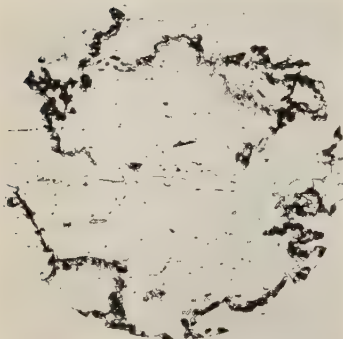
FIG. 25.—Annealed at 700°C. for 24 hours after rolling (reduction 8·3 per cent.); then again annealed at 725°C. for 24 hours. ×100.
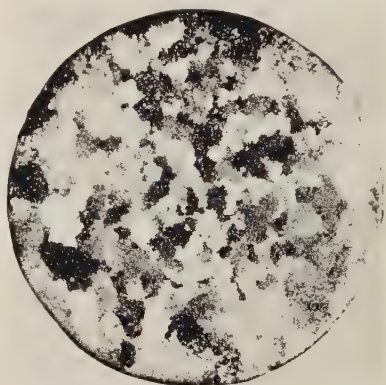
FIG. 26.—Slowly heated from 600°C. to 690°C. during 48 hours after straining 7 per cent. ×4.
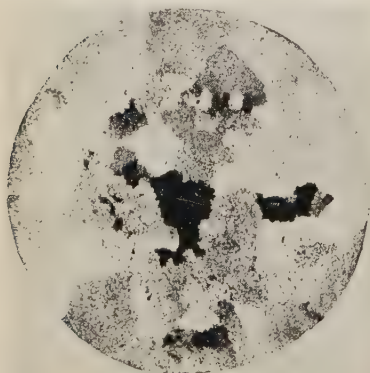
FIG. 27.—Heated slowly from 500°C. to 715°C. during 7 days after straining 6 per cent. ×4.
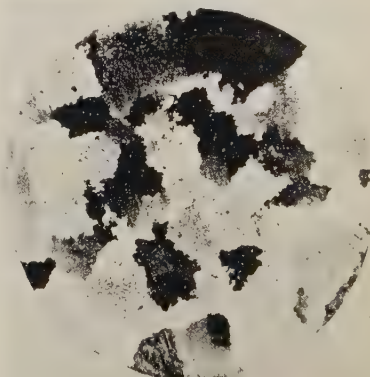
FIG. 28.—Heated slowly from 500°C. to 715°C. during 7 days and then at 760°C. for 24 hours after straining 6 per cent. ×4.

PLATE XXXVI.
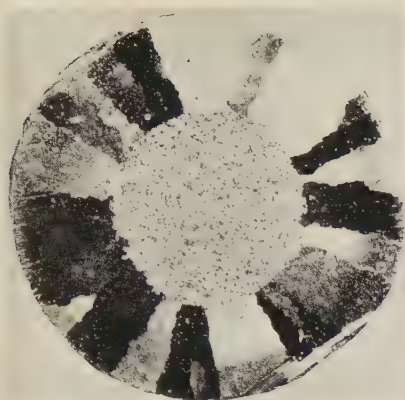
FIG. 29.—Normalised at 950°C., followed by annealing at 725°C. in air ; previous strain 5 per cent. ×4.
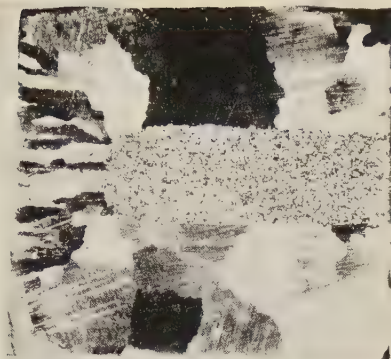
FIG. 30.—Same as Fig. 29; with the grain. ×4.
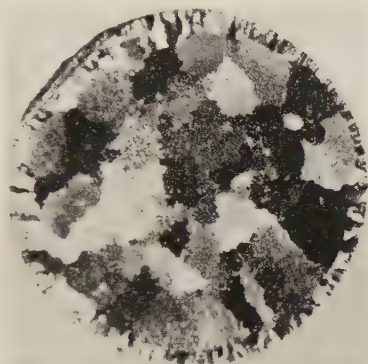
FIG. 31.—Slightly carburised on surface : annealed at 950°C., followed by annealing at 725°C. for 24 hours ; previous strain 5 per cent. ×4.

FIG. 32.—Showing cementite at ferrite boundaries in columnarised section of Fig. 29. ×100.

(2) When the annealing temperature is 725° C. and the time 24 hr., if decarburisation takes place, large columnar crystals grow in the specimens strained 4 to 6 per cent., but not in unstrained specimens.

(3) When decarburisation occurs, this change in some way prevents the growth of equiaxed crystals in the interior of critically strained material. In other words, a greater degree of straining is needed to produce large crystals in the centre under decarburising conditions. The effects in this connection are indicated in Table II. :

TABLE II.

Annealing Temperature. ° C.	Strain to give Columnar Crystals in Outside Parts. %	Strain to give Polygonal Crystals Inside. %	Atmosphere in Furnace.	Material before Treatment.
675	4	Over 5	Air	Ordinary
700	4 to 5	,, 6	,,	,,
725	4 to 6	,, 7	,,	,,
725	No growth	,, 4	Coal-gas	Deeply decarburised
725	No growth	,, 5	Air	Slightly decarburised

(4) The higher the annealing temperature, the greater is the amount of strain which is, so to speak, neutralised inside the bar by the development of columnar crystals at the rim.

(5) The higher the temperature and the greater the strain (within certain limits), the greater is the extent of columnar crystal growth. This may be, in part, due to an increase in the rate of carbon removal.

(6) When decarburisation occurs there is a tendency for cementite to migrate to, and form thin films at, the new ferrite boundaries.

This question of the formation of columnar crystals in mild steel is one of considerable importance, and it would be very useful if some convenient practical means could be devised to prevent its occurrence. For example, in the case of highly finished mild steel sheets, such as are used for motor-car bodies, this kind of coarse crystallisation often occurs ; and, in many instances, it is so objectionable that white annealing, after a cold-rolling finish, has to be dispensed with in order to avoid the development of this structure. Coarse crystals of this kind, near the surfaces

M

of such sheets, cause a roughening during the drawing process to such an extent that it shows through the coating of paint and renders the material unsuitable for many classes of work.

Whilst it would be going too far to say that the authors have given sufficient attention to the practical aspects of this problem to warrant their making a definite suggestion to overcome this difficulty, they feel the data contained in this paper should be useful in that direction.

There appear to be two possible directions which offer helpful prospects of preventing this kind of crystallisation. The first is to increase substantially the degree of cold-rolling to a range beyond that at which columnarisation of the surface will develop when the material is subjected to white annealing. This would not only improve the surface quality or finish, but it would also cause complete refining by recrystallisation. The second possibility is to prevent the loss of carbon during the annealing process. This might be done by spraying the surfaces, prior to introducing the sheets into the annealing pot, with a thin coating of graphite. This would tend to prevent loss of carbon, but at white-annealing temperatures, that is, below 700° C., it would not cause carburisation. It should, perhaps, be pointed out that the loss of carbon from the steel is not only determined by the chemical nature of the atmosphere round the metal, but there are good reasons for thinking that it is materially aided by the oxygen content of the steel itself. Even this, however, the authors feel would be counteracted by the presence of carbon on the outside surfaces of the sheets.

REFERENCES.

(1) J. E. STEAD : " Brittleness produced in Soft Steel Sheets by Annealing," *Journal of the Iron and Steel Institute*, 1898, No. II. p. 137.
(2) C. CHAPPELL : " Recrystallisation of Deformed Iron," *Journal of the Iron and Steel Institute*, 1914, No. I. p. 460.
(3) C. A. EDWARDS and L. B. PFEIL : " A Note on Coarse Crystallisation in Mild Steel Sheets," *Journal of the Iron and Steel Institute*, 1923, No. II. p. 263.
(4) Z. JEFFRIES : " Grain-Growth in Metals," *Journal of the Institute of Metals*, 1918, No. 2, p. 109.
(5) C. J. SMITHELLS : " The Effect of Impurities on Recrystallisation and Grain-Growth," *Journal of the Institute of Metals*, 1922, No. 1, p. 107.
(6) H. C. H. CARPENTER and C. F. ELAM : " Crystal Growth and Recrystallisation in Metals," *Journal of the Institute of Metals*, 1920, No. 2, p. 83.

(7) C. A. EDWARDS and L. B. PFEIL : " The Production of Large Crystals by Annealing Strained Iron," *Journal of the Iron and Steel Institute*, 1924, No. I. p. 129.

(8) J. E. STEAD : " The Crystalline Structure of Iron and Steel," *Journal of the Iron and Steel Institute,* 1898, No. I. p. 145.

(9) C. R. AUSTIN : " Hydrogen Decarburisation of Carbon Steels, with Considerations of Related Phenomena," *Journal of the Iron and Steel Institute*, 1922, No. I. p. 93.

Additional References not Mentioned in the Text.

A. JOISTEN : *Metallurgie*, 1910, vol. vii. p. 456.

H. LE CHATELIER : *Revue de Métallurgie, Mémoires*, 1911, vol. viii. p. 367.

A. SAUVEUR : *Proceedings of the International Association for Testing Materials*, New York, Sept. 1912.

R. M. SHERRY : *Metallurgical and Chemical Engineering*, 1912, vol. x. p. 666.

F. ROBIN : *Revue de Métallurgie, Mémoires*, 1913, vol. x. pp. 722, 758.

W. E. RUDER : *Transactions of the American Institute of Mining Engineers*, 1913, vol. lxvii. p. 569.

ANDERSON : *Transactions of the Faraday Society*, July 23, 1918.

D. HANSON : *Journal of the Institute of Metals*, 1918, No. 2, p. 141.

R. SELIGMAN and P. WILLIAMS : *Journal of the Institute of Metals*, 1918, No. 2, p. 162.

H. C. H. CARPENTER and C. F. ELAM : *Proceedings of the Royal Society*, 1921, A, vol. c. p. 329.

H. C. H. CARPENTER : *Journal of the Iron and Steel Institute*, 1923, No. I. p. 175.

E. D. CAMPBELL : *Journal of the Iron and Steel Institute*, 1919, No. II. p. 407.

E. D. CAMPBELL, J. F. ROSS, and W. L. FINK : *Journal of the Iron and Steel Institute*, 1923, No. II. p. 179.

H. C. WANG : *Journal of the Iron and Steel Institute*, 1923, No. II. p. 285.

M. POLANYI : *Zeitschrift für Elektrochemie*, 1922, Jan. 1, p. 16.

CORRESPONDENCE.

Mr. A. ALLISON (Sheffield) wrote that it was to be regretted that the authors had had to omit, under the necessity for abbreviation, the technical details of their experiments with sheets, whilst retaining the more academic matters connected with bars. From previous papers it was to be assumed that the sheet steels were of thin gauge, and hence were much more sensitive and subject to varying conditions than heavier gauge sheets. For example, he (Mr. Allison), in experimenting with sheets 0·107 in. thick, had obtained a critical degree of strain rather different from that of the authors; the analyses of the steels were as follows :

	Carbon. %	Manganese. %	Sulphur. %	Phosphorus. %
Steel *A* . . .	0·14	0·43	0·039	0·024
,, *B* . . .	0·04	0·29	0·045	0·016

Annealing for 6 hr. gave the following results :

Annealing Temp. ° C.	Degree of Strain producing Largest Grain Growth.	
	A. %	*B.* %
625	...	7·9
675	8·5	7·9
740	8·5	...

The strain was produced by cold-rolling.

He (Mr. Allison) was in agreement with the authors upon the number of variables concerned—namely, variation in the steel, loss of carbon in hot-rolling, and, what was very surprising, loss of carbon in close annealing at temperatures below 700° C. He would suggest that experiments with heavy gauge material would give more precise results, also that tensile strain and cold-rolling strain were not strictly comparable, since, as the authors admitted, in tensile straining the presence of pearlite gave rise to inequality of strain.

In the results given above, it would appear evident that the analysis of the two pieces accounted for the difference in grain-growth, since, as the authors pointed out, the carbide of iron acted as a barrier to grain-growth.

The authors were to be congratulated on presenting further evidence that columnar grain-growth was largely produced by surface decarburisation, since that was a very important matter in the production of bright steel sheets.

He (Mr. Allison) would like to ask if the authors had not, on occasion, found a segregated centre layer in sheets with large surface crystals, as it appeared to him that, since much dead mild basic steel was cast into ingots with a core richer in impurities, such steel when rolled into

sheets would be harder in the centre, with correspondingly greater strain effects upon the surface layers.

The suggestions made by the authors for avoiding surface troubles were also likely to prove valuable in practice.

Mr. J. H. WHITELEY (Consett) wrote : I am sure it will be generally agreed that the authors have given a paper of great interest, especially to those engaged in the manufacture of mild steel sheets, and that they have done some excellent experimental work. Further, work of the same kind is obviously needed on other varieties of soft steel. In particular, the effect of a higher manganese content might be considered, for it is certainly on the low side in the sample the authors have used. I would suggest also that the effect on grain-growth of repeated straining and annealing should be investigated. As regards the prevention of decarburisation in annealing, I would point out that when several samples of steel are annealed together in a non-oxidising atmosphere, one steel may rob another of its carbon. I have several times observed this effect. There is no need even for the samples to be in contact. Whether this peculiar redistribution of the carbon occurs when coal-gas is used I am unable to say, but I think that to remind the authors of this possibility may not be out of place.

Professor EDWARDS, in reply, wrote thanking Mr. Allison and Mr. Whiteley for their contributions to the discussion. He was particularly pleased to have Mr. Allison's interesting statements concerning the critical strains that he had found to be associated with two steels quoted. The authors had very reluctantly decided to refrain from giving full details of their experiments relating to sheet material, the reason being that the variables were so disturbing as to make it less easy for the reader to grasp the full significance of the fundamentals relating to grain-growth in material of the kind examined.

With regard to Mr. Allison's question concerning columnar grain-growth produced by surface decarburisation, he (Professor Edwards) had to say that the authors had not observed any special peculiarity in that connection which could be definitely traced to the segregated central portions of an ingot ; there was, however, every reason to suppose that such segregation would have a marked effect on the behaviour of the material.

Mr. Whiteley would be interested to know that he (Professor Edwards) now had in hand an extensive investigation bearing on the influence of varying quantities of manganese on mild steel sheets and rods.

THE CHANGE IN TENSILE STRENGTH DUE TO AGEING OF COLD-DRAWN IRON AND STEEL.*

By L. B. PFEIL, D.Sc., A.R.S.M.
(UNIVERSITY COLLEGE, SWANSEA).

SUMMARY.

In the experimental work described in this paper the tensile test was employed as a measure of the capacity of the metal to undergo age-hardening after cold-drawing, and it is shown that the phenomenon is chiefly due to the presence of carbon. Carbon-free iron is not subject to ageing, but iron containing as little as 0·0025 per cent. of carbon shows well-developed ageing. Iron containing ferrous oxide also exhibits the phenomenon. It is suggested that both carbon and iron oxide are soluble to a small extent in ferrite at ordinary temperatures, but that the solubility is less in distorted crystals, with the result that hardening and strengthening of the " duralumin " type occurs after cold-working.

INTRODUCTION.

Essentially, the experimental work described in this paper consisted of the cold-drawing without annealing of a series of steels of varying carbon content and also of varying heat treatment, followed in all cases by tensile tests at different stages of reduction and at different lengths of time after the drawing. The procedure in cold-drawing was as follows : The annealed metal $\frac{1}{2}$ in. in diameter was drawn from 6/0 S.W.G. to 16 S.W.G. without annealing, each die decreasing the diameter by approximately one gauge number. The drawing was carried out at the very slow rate of 3 in. per minute, so as to minimise any tendency to spontaneous annealing due to rise in temperature.

The material under investigation was mild steel of the follow-
ing composition :

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0·11	0·006	0·70	0·028	0·016 per cent.

To produce low carbon contents the steel was decarburised by
heating in hydrogen for prolonged periods.

EXPERIMENTAL RESULTS.

The effect of cold-drawing on the tensile strength of the mild
steel and the decarburised iron is shown by the results in Table I.,
columns A, B, D, and E, and graphically in Fig. 1. For each of
the materials, results are given for tensile tests made immediately
after drawing (within 5 minutes) and after ageing for 1 month
(28 days). Curve 1 refers to the mild steel tested immediately,
and curve 2 to the same steel after ageing. The increase in tensile
strength due to ageing amounts on the average to 2·32 tons per
sq. in. Column F, Table I., shows that this increase is constant
within the limits of experimental error for all reductions.
(Reduction figures are calculated as the percentage decrease in
cross-sectional area.) The mild steel used for these experiments
was slowly cooled from 950° C. The microstructure showed
finely crystalline ferrite and pearlite, as illustrated at 500 diam. in
Fig. 2 (Plate XXXVII.). Curve 3 in Fig. 1 corresponds with two
sets of points, one set for carbon-free iron tested immediately after
drawing, and one set for carbon-free iron tested one month after
drawing. It will be seen that cold-drawn carbon-free iron does
not suffer an increase in strength due to ageing. The micro-
structure of this material is shown in Fig. 3. The carbon was
removed by heating the mild steel for six weeks in a hydrogen
stream at 750° C., followed by slow cooling, producing a structure
consisting of ferrite grains with some non-metallic inclusions.

Reference should perhaps be made to the reason for the choice
of one month as the standard time of ageing. In Table II. are
given the results of tests on two lots of cold-drawn 0·11 per cent.
carbon steel, from which it will be observed that the great majority
of the increase in strength occurred during the lapse of the first
month. The plotting of these points gives a smooth curve,
rising very rapidly at first and gradually becoming nearly parallel

TABLE I.—*Effect of Cold-Drawing on the Tensile Strength of Mild Steel and Decarburised Iron.*

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Carbon = Nil.			Carbon = 0·11%.			Carbon = 0·11%.		Carbon = 0·038%.			Carbon = 0·014%.		
Reduction. %	Immediate.	Aged.	Difference.	Immediate.	Aged.	Difference.	Aged 2 Months.	Difference.	Immediate.	Aged.	Difference.	Immediate.	Aged.	Difference.
0	18·4	...	...	23·15	...	...	...	...	20·6	...	...	20·3	...	...
11·2	21·95	21·7	− 0·25	27·4	29·4	2·0	30·2	2·8	24·8	27·05	2·25	24·85	28·35	3·5
22·8	24·65	24·6	− 0·05	30·9	33·0	2·1	33·3	2·4	27·75	30·0	2·25	27·85	31·35	3·5
36·0	26·4	26·5	+ 0·1	33·15	35·6	2·45	35·5	2·35	29·5	32·1	2·6	29·6	33·0	3·4
44·0	27·8	27·7	+ 0·1	35·0	37·2	2·2	37·5	2·5	30·8	33·6	2·8	31·15	34·6	3·45
52·8	29·0	29·0	0	36·5	39·0	2·5	39·0	2·5	32·2	35·2	3·0	32·15	35·8	3·65
61·2	30·2	30·0	− 0·2	37·6	40·3	2·7	40·5	2·9	33·7	36·2	2·5	33·15	36·7	3·55
68·2	31·0	31·0	0	38·9	41·75	2·85	41·9	3·0	34·9	37·6	2·7	34·0	37·5	3·5
75·3	32·8	32·6	− 0·2	41·1	43·85	2·75			36·15	38·9	2·75	34·8	38·0	3·2
77·8	33·2	33·2	0	41·85	44·3	2·45								
81·2	34·0	34·2	+ 0·2	42·95	45·25	2·35								
85·0	35·3	35·75	+ 0·45	44·9	46·9	2·0								
86·2	36·2	36·1	− 0·1	46·4	48·2	1·8								
88·4	37·4	37·3	− 0·1	47·8	49·8	2·0								
90·5	38·8	38·7	− 0·1	49·9	51·9	2·0								
93·0	42·2	42·0	− 0·2	53·7	56·1	2·4								
94·5	43·6	43·2	− 0·4	55·8	58·3	2·5								
95·3	44·7	44·5	− 0·2	57·0	59·5	2·5								
96·45	47·8	47·8	0	60·3	63·2	2·9								
97·68	51·5	52·3	+ 0·8	63·4	66·0	2·6								
98·14	55·1	55·6	+ 0·5	67·1	68·4	1·3								
	Average difference, zero			Average difference, 2·32					Average difference, 2·62			Average difference, 3·47		

with the time axis. The figures given in Table I., columns G and H, are of interest in this connection. Comparing columns G
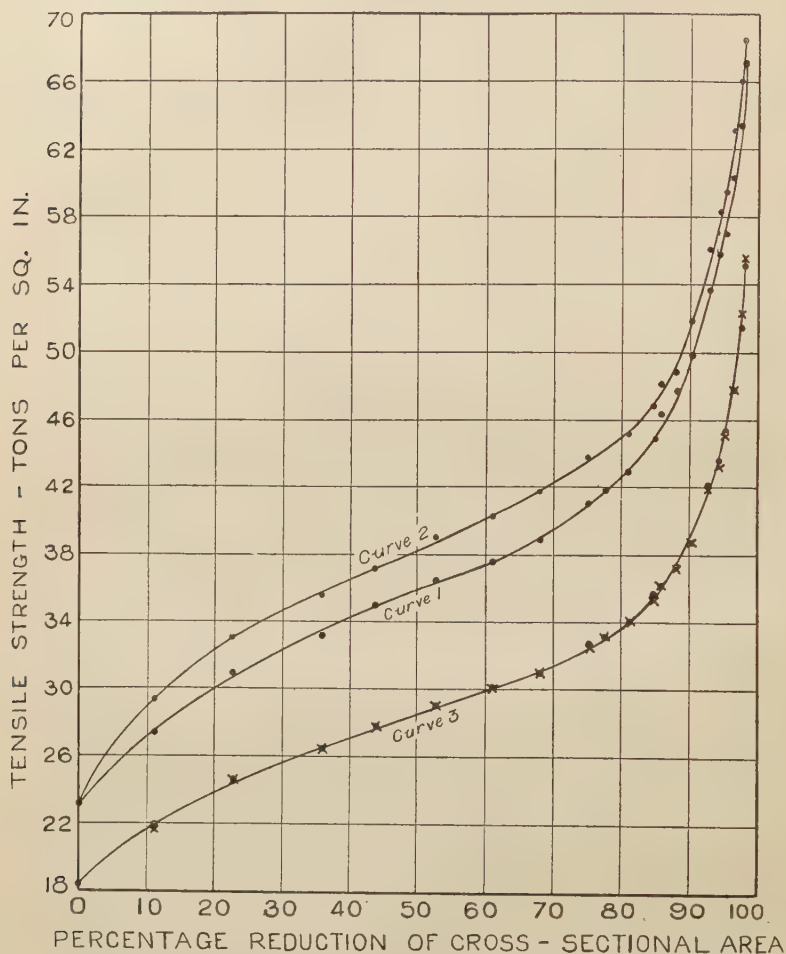
Fig. 1.—The Relation between Percentage Reduction of Area by Cold-Drawing and the Tensile Strength for Low-Carbon Steel and Carbon-Free Iron.

and E, it will be seen that only very small changes occurred during an extra one month's ageing.*

* No increase in strength could be obtained in the case of carbon-free iron either by ageing at atmospheric temperature for six months or by annealing at a low temperature.

TABLE II.—*Rate of Increase of Strength by Lapse of Time.*

0·11% *Carbon Steel Annealed at* 900° *C.*

Drawn to 22·8% Reduction in 2 Passes.			Drawn to 61·2% Reduction in 6 Passes.		
Length of Time after Drawing.	Tensile Strength. Tons per sq. in.	Increase in Strength. Tons per sq. in.	Length of Time after Drawing.	Tensile Strength. Tons per sq. in.	Increase in Strength. Tons per sq. in.
0	30·9	...	0	37·6	...
10 min.	31·0	0·1	4 hr.	37·75	0·15
70 ,,	30·8	— 0·1	26 ,,	38·0	0·4
170 ,,	30·9	0	6 days	39·0	1·4
6 hr.	31·0	0·1	23 ,,	39·55	1·95
23 ,,	31·15	0·25	37 ,,	40·0	2·4
5 days	31·6	0·7	113 ,,	40·4	2·8
12 ,,	32·1	1·2			
29 ,,	32·6	1·7			
43 ,,	33·0	2·1			
119 ,,	33·1	2·2			

The results so far obtained show clearly that age-hardening is associated with the presence of carbon.

EFFECT OF STRUCTURAL CONDITION OF CARBON.

Before proceeding further, an attempt was made to determine whether steel with a structure other than ferrite plus pearlite would exhibit the age-hardening phenomenon. Some of the 0·11 per cent. carbon steel was heat-treated so as to cause the divorce of the pearlite, producing a structure consisting of ferrite grains with the carbon in the form of globules of cementite. This steel was cold-drawn and tested as before. Comparing the results with those from similar steel annealed at 950° C., it was seen that although the tensile tests on the divorced steel were markedly lower than corresponding tests on the pearlite steel, the increase in strength due to ageing was not appreciably different in the two cases. Thus it appeared that, although the presence of carbon was necessary for the phenomenon of age-hardening, the structural nature of the carbon was of negligible importance.

RELATION BETWEEN CARBON CONTENT AND AGEING CAPACITY.

Experiments were then made to find at what carbon content the ageing effect disappeared. A series of steels of varying carbon content was prepared by decarburising the original 0·11 per cent. carbon steel for varying lengths of time. Bars were heated in a stream of hydrogen at 950° C. for from 6 days to 5 weeks, followed in each case by heating for one week at the same temperature with no flow of gas in order to allow the remaining carbon, if any, to become more uniformly distributed by diffusion. The bars were then cold-drawn and tested as before. The results for four different degrees of cold-working are given in Table III. In Table I., columns I, J, L, and M, figures are also given for two partly decarburised steels with carbon contents of 0·038 and 0·014 per cent. These results cover reductions by cold-drawing

TABLE III.—*Effect of Carbon on Age-Hardening Capacity.*

Degree of Cold-Work. %	Tensile Strength. Tons per sq. in.		Increase in Strength. Tons per sq. in.	Carbon. %
	Immediate.	After 1 Month.		
22·8	30·9	33·0	2·4	0·110
	27·85	31·35	3·5	0·014
	26·6	29·0	2·4	0·011
	26·15	29·0	2·85	0·0055
	25·9	28·7	2·8	0·004
	26·35	28·6	2·25	0·0025
	25·4	25·6	0·2	0·0015
	24·4	24·65	0·25	Zero
44·0	35·0	37·2	2·2	0·110
	30·2	32·5	2·3	0·023
	29·65	32·15	2·5	0·006
	28·3	28·75	0·45	0·002
	27·8	28·25	0·45	Zero
52·8	36·5	39·0	2·5	0·110
	32·15	35·8	3·65	0·014
	30·7	33·55	2·85	0·003
	29·5	29·8	0·3	0·001
	29·4	29·4	Zero	Zero
61·2	37·6	40·3	2·7	0·110
	33·15	36·7	3·55	0·014
	31·95	35·0	3·05	0·003
	30·45	30·85	0·4	0·001
	30·2	30·3	0·1	Zero

up to 75 per cent., and are of considerable interest when considered in conjunction with the results in Table III. From Table III. it will be seen that the capacity for ageing remained very marked, until nearly all the carbon had been removed. It appeared as if the decrease in carbon at first caused a small increase in age-hardening capacity, but as the carbon fell below about 0·0025 per cent. the age-hardening effect suddenly fell to nearly zero. In considering these figures it must be borne in mind that the experimental error in determining the tensile strengths was probably of the order of ± 0·2 ton per sq. in., so that in the difference column errors as great as ± 0·4 ton might be found. Further, owing to the variation in time of annealing, there was a variation in crystal size in these specimens, and there is some reason to suppose that this factor has a bearing on the ageing capacity of cold-drawn iron and steel. Up to the present the effect of crystal size in this connection has not been studied sufficiently to allow any definite conclusions to be drawn. Chemical analysis showed that the hydrogen annealing caused no change in the phosphorus, manganese, silicon, or sulphur content of the steel.

Estimation of Carbon.

Brief reference must here be made to the method adopted for the determination of carbon in these materials. The steel was dissolved in copper potassium chloride solution and the residue burnt in oxygen. This method has the advantage of allowing very large weights to be taken in the case of samples of low carbon content, thus materially decreasing the errors ; weights from 100 to 10 grm. were employed, according to the probable carbon content. Reasonably consistent results were obtained when check determinations were made, and accurate results were obtained when standard steels were used to check the experimental conditions. While no claim is made for great accuracy when the carbon was extremely low, it is considered that the carbon figures quoted in this report are reliable to within ± 10 per cent. when the carbon exceeded 0·01 per cent., but that below this amount the results are reliable only within the following limits :

Carbon = 0·005 ± 0·001 per cent., and carbon = 0·001 ± 0·0005 per cent.
(0·001 per cent. of carbon on 100 grm. = 0·0037 grm. of CO_2.)

These limits are in accordance with the variations found by check determinations, but the possibility must be faced that carbon in solution in ferrite is not wholly recovered by the separation employed. It has not been possible to test this point, but it is not considered that the conclusions reached in this paper would be fundamentally affected even if all the carbon results quoted are low.

Each sample for analysis was turned from the parallel portion of a test-piece, using the whole cross-section and an approximately equal quantity from either side of the fracture. Care was taken throughout the whole course of the estimation to avoid contamination of the samples by oil, dust, &c. The percentage carbon figures given in the tables are generally the average values from corresponding " immediate " and " aged " test-pieces.

EXPLANATION OF RESULTS.

The research had now reached a stage when it was clear that the variation in strength of cold-drawn steel on ageing was due to the presence of carbon, the amount of carbon required being so little as to be easily overlooked during microscopical observations, and possibly present in amounts so small as to be wholly in solution in the ferrite.

It is considered that the ageing effect is solely due to the carbon in solution in the ferrite crystals, and that the solubility of carbon in cold-worked ferrite is less than in annealed ferrite, with the result that, after cold-working, the carbon dissolved in the ferrite is slowly precipitated as hard minute particles of cementite, thus leading to a gradual increase in strength with the passage of time. This would be a phenomenon very similar to the age-hardening of quenched duralumin and other non-ferrous alloys. The exact solubility of carbon in ferrite at ordinary temperatures cannot yet be regarded as accurately known. The results of this research indicate the value 0·0025 per cent., but, as already indicated, the author is not convinced that carbon in solution in ferrite can be determined with accuracy by the copper chloride method, so that the true solubility might be appreciably higher than this figure. On the other hand, in steels so low in carbon as this it is almost impossible to detect with certainty whether traces of

free carbide are present, so that the solubility might conceivably be even less than the figure quoted. Fig. 4 (Plate XXXVII.) illustrates the structure of iron containing 0·004 per cent. of carbon, and should be compared with Fig. 3, which shows iron free from carbon. Both specimens were etched in 5 per cent. picric acid under similar conditions. The black specks in the micrographs, particularly in Fig. 4, are non-metallic inclusions. Carbon, when present in small quantities, appears as cementite films at the grain boundaries.

FURTHER EXPERIMENTAL WORK.

Most of the material so far employed had cooled from 950° C. to 100° C. in about 12 hr., and it seemed possible that if the material were cooled more rapidly more carbon would be retained in solution in the ferrite, and as a consequence the age-hardening effect be more marked. Bars of varying carbon content were cooled from 950° C. in furnaces with different rates of cooling. Some bars were also wrapped up in thin sheet iron to prevent excessive oxidation, and allowed to cool rapidly from 950° C. in air. Two sets of results are given in Table IV., from which it will be clear that, in steel containing 0·1 per cent. of carbon, rapid cooling, though resulting in higher values for tensile strength, does not result in an increase in the ageing capacity. Since these experiments were carried out, a paper has been published

TABLE IV.—*Effect of Rate of Cooling on the Capacity for Age-Hardening of 0·11 per cent. Carbon Steel.*

Reduction. %	Slow Furnace-Cooling. Tensile Strength. Tons per sq. in.			Rapid Air-Cooling. Tensile Strength. Tons per sq. in.		
	Immediate.	Aged.	Difference.	Immediate.	Aged.	Difference.
0	23·15	...	...	25·15	...	...
11·2	27·4	29·4	2·0	29·35	31·25	1·9
22·8	30·9	33·0	2·1	32·8	34·7	1·9
36·0	33·15	35·6	2·45	35·0	36·7	1·7
44·0	35·0	37·2	2·2	37·2	39·3	2·1
52·8	36·5	39·0	2·5	39·0	41·0	2·0
61·2	37·8	40·3	2·7	40·9	42·35	1·45
68·2	38·9	41·7	2·8	42·4	44·3	1·9
			Average, 2·35			Average, 1·85

by Whiteley,[1] in which it is clearly shown that the rate of separation of carbon from ferrite is exceedingly rapid, thus making it probable that all rates of cooling employed in the present research were too slow to make any appreciable difference to the amount of carbon retained in solution in the ferrite.

In the case of material free from carbon, surprising results were obtained from samples rapidly cooled in air. The carbon-free material, which in previous experiments gave zero values for age-hardening, now gave values as large as those obtained in any previous experiments. The regained ageing capacity was due either to the change in the rate of cooling, or to the change in the annealing atmosphere from hydrogen to air. Experiments soon showed that the age-hardening capacity was due in some way to the bars having been heated in air, and was in no way connected with the alteration in the rate of cooling.

To test further the effect of heat treatment in an oxidising atmosphere, a series of bars which had been heated for prolonged periods in hydrogen, thus reducing their carbon content to very small amounts and in some cases to zero, were reheated for varying lengths of time under oxidising conditions of varying severity. In one experiment bars were heated in moist cylinder nitrogen, in another experiment in a furnace through which a stream of air was drawn, and in a third case in a furnace with a stationary air atmosphere. Bars before and after oxidising annealing were cold-drawn, and tensile tests were made both immediately after drawing and after ageing for one month. The results of some of these tests are given in Table V. The first portion of the table refers to the materials FH and FA. FH had been heated for 3 weeks in a hydrogen stream at 950° C., after which it was found to contain 0·011 per cent. of carbon in the form of pearlite, the carbon being rather higher in the centre than at the periphery. FA was the same material as FH, but had in addition been reheated at 950° C. for 2 days in an air atmosphere. FA contained only 0·006 per cent. of carbon, 0·005 per cent. having been lost during the final oxidising annealing. The surface of these bars was scaled to a depth of about 0·001 in.

Comparing the figures obtained from these two sets of tests, it will be seen that there are no very marked differences. In the case of the two sets of " immediate " tests, FA results are,

PLATE XXXVII.

FIG. 2.—0·11 per cent. Carbon Steel, slowly cooled from 950° C.   ×500.
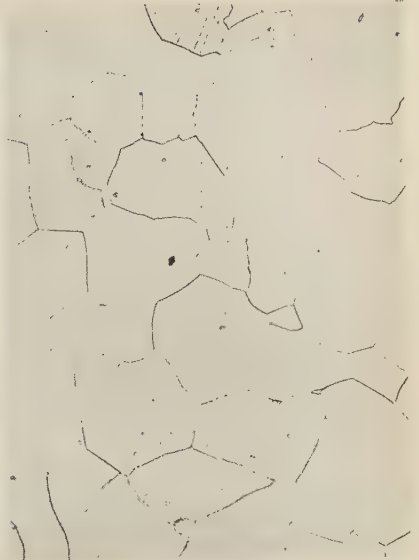
FIG. 3.—Carbon-free Iron, etched in 5 per cent. Picric Acid in Alcohol.   ×100.

FIG. 4.—Iron containing 0·004 per cent. Carbon.   Etched in Picric Acid.   ×100.

FIG. 5.—Iron containing Oxide absorbed during annealing in air at 950° C.   ×500.

on the whole, slightly lower than those of *FH*. On the other hand, the ageing results for *FA* are slightly higher than for *FH*,

TABLE V.—*Effect of Oxidising and Reducing Annealing on the Ageing Capacities of Iron and Low-Carbon Steel.*

Reduc-tion. %	Material FH : Heated in Hydrogen only. Carbon = 0·011 per cent.			Material FA : Material FH heated for 2 days in Oxidising Atmosphere. Carbon = 0·006%.			Change in Ageing Capacity. Tons per sq. in.
	Tensile Strength. Tons per sq. in.			Tensile Strength. Tons per sq. in.			
	Immediate.	Aged.	Difference.	Immediate.	Aged.	Difference.	
0	20·0	...	...	20·3	...	...	...
11·2	24·5	26·8	2·3	24·0	26·7	2·7	+ 0·4
22·8	27·2	29·6	2·4	26·7	29·5	2·8	+ 0·4
36·0	28·8	31·4	2·6	28·8	31·9	3·1	+ 0·5
44·0	30·35	33·0	2·65	30·0	33·2	3·2	+ 0·65
52·8	31·5	34·3	2·8	31·3	34·8	3·5	+ 0·7
61·2	32·5	35·4	2·9	32·55	36·1	3·55	+ 0·65
68·2	33·4	36·2	2·8	33·4	37·15	3·75	+ 0·95
	Average difference, 2·68			Average difference, 3·23			Average, + 0·61
	Material AH : Heated in Hydrogen only. Carbon = zero.			Material AA : Material AH heated for 2 days in Oxidising Atmosphere. Carbon = zero.			
0	18·4	...	...	19·2	...	...	...
11·2	21·95	21·7	− 0·25	22·8	25·4	+ 2·6	+ 2·85
22·8	24·65	24·6	− 0·05	25·4	28·05	+ 2·65	+ 2·7
36·0	26·4	26·5	+ 0·1	27·3	30·3	+ 3·0	+ 2·9
44·0	27·8	27·75	− 0·05	28·4	31·6	+ 3·2	+ 3·25
52·8	29·0	29·0	Zero	29·7	33·0	+ 3·3	+ 3·3
61·2	30·2	30·0	− 0·2	30·8	34·3	+ 3·5	+ 3·7
68·2	31·0	31·0	Zero	31·8	35·5	+ 3·7	+ 3·7
	Average difference, − 0·08			Average difference, + 3·14			Average, + 3·2
	Material D : Heated in Air. Carbon = zero.			Material DH : Material D heated for 3 days at 950° C. in Hydrogen. Carbon = zero.			
0	19·4	...	...	19·2	...	...	...
14·5	23·5	26·8	3·3	23·35	25·7	2·35	− 0·95
27·5	26·8	29·8	3·0	26·45	28·8	2·35	− 0·65
39·0	28·5	31·2	2·7	28·35	30·8	2·45	− 0·25
50·0	29·85	32·6	2·75	29·6	32·0	2·4	− 0·35
58·8	30·95	33·6	2·65	30·7	33·4	2·7	+ 0·05
67·9	32·1	34·8	2·7	31·8	34·6	2·8	+ 0·10
	Average difference, 2·85			Average difference, 2·51			Average, − 0·34

so that the oxidising annealing has caused a small increase (average value, 0·6 ton per sq. in.) in the ageing capacity of this material. In the light of experimental results to follow, these results are interpreted as follows : The carbon present was sufficient to prevent the absorption of all but a superficial layer of oxide during the oxidising annealing treatment. That is to say, that oxide entering the metal was reduced by the carbon present, and about half the carbon was lost in this way. In the major portion of the bars of *FA* there was still sufficient carbon left to produce well-developed ageing effects (above 0·0025 per cent.), while near the surface there was oxide in the ferrite grains which, as will be shown later, is an important factor in the phenomenon of ageing. The " immediate " results for *FA* are lower than those of *FH*, owing to the lower carbon content, while the " aged " results of *FA* are higher than those of *FH*, owing to oxide having a more powerful ageing effect than carbon. Microscopical investigation supported the explanation advanced for these results.

The middle part of Table V. refers to materials *AH* and *AA*. These samples had been annealed in hydrogen until the whole of the carbon was removed, after which *AA* had been heated in a slow stream of air for 2 days at 950° C. *AA* was thus scaled to a depth of about 0·001 in. The " immediate " results for *AH* are much lower than those for *FH*, owing to the entire absence of carbon in *AH*. The " aged " results for *AH* are practically the same as the " immediate " results for the same specimen, indicating the complete absence of ageing capacity. The " immediate " results for *AA* are higher than the " immediate " results for *AH* by an average of 0·75 ton per sq. in. This increase in strength can only be due to oxygen absorbed by the steel from the oxidising atmosphere. The " aged " results for *AA* show a very marked increase over the " immediate " results for the same material, amounting on the average to an increase of 3·14 tons per sq. in. The significance of these results will be discussed after considering the results in the third section of Table V.

The third section of Table V. deals with materials *D* and *DH*. These specimens were completely decarburised by heating for 3 weeks at a temperature of 950° C. in an air atmosphere which was so controlled that excessive scaling was avoided.

After removing the scale by acid pickling the surface of the bars was rough, and they were therefore drawn cold from 0·5 in. to 0·42 in. (25 per cent. reduction) in two passes to give a smooth surface, and then annealed at 950° C. in nitrogen.   This treatment produced the material D.   One-half of the bars were then heated at 950° C. for 3 days in a hydrogen stream, these hydrogen annealed bars being designated DH.   Bars of D and DH were then drawn down and tested as before.   The figures given in the third section of Table V. cannot be compared directly with those in the two previous sections, owing to the reductions being somewhat different, but from the corresponding curves (not reproduced) it could be seen that the " immediate " figures for D (decarburised in air) were, on the average, 1·2 tons per. sq. in. above those for AH (decarburised in hydrogen).   After ageing for one month the tensile strength of bars D had increased by an average of 2·85 tons per sq. in., while the middle section of Table V. shows that AH was unaffected by ageing.   The results given for DH show that the hydrogen treatment given to D produced a decrease in " immediate " tensile tests of 0·24 ton per sq. in. (average value), and a decrease in the " aged " tensile tests of 0·54 ton per sq. in. (average value).   Thus, annealing in hydrogen reduced the ageing capacity by 0·35 ton per sq. in. (from 2·85 to 2·51 tons per sq. in.).   It will be seen that, although in the specimens D and DH the annealing procedure has been reversed, that is, the oxidising anneal came first and the reducing anneal second, the results tend to confirm the previous finding that an oxidising anneal causes an increase in the ageing capacity.

It is interesting to note that Rooney [2] has shown that heating iron containing oxygen in a stream of hydrogen gas at 900° C. for prolonged periods only removes about half the total oxygen present, and that a temperature of 1150° to 1200° C. is probably required for the complete removal of oxygen.   In view of Rooney's results, which refer to iron in the form of millings, it seems probable that if these oxidised bars, 0·42 in. in diameter, had been heated in hydrogen for longer times at higher temperatures a much more convincing decrease in ageing capacity would have been found.

The assumption that the ageing capacity found in carbon-free iron after the oxidising treatment is due to the absorption of

oxygen is strengthened by the microscopical examination of the specimens. Cross-sections of the oxidised bars showed, both in the etched and unetched conditions, dark particles occurring in large numbers near the periphery of the section, and becoming less numerous in passing towards the centre. Fig. 5 shows a field near the edge of a section at a magnification of 500 diam. The dark globules dispersed through the crystals are assumed to consist of ferrous oxide. This photograph should be compared with those published by Tritton and Hanson.[3] The oxide must have entered the metal during the oxidising anneal, for this structure was not exhibited by any specimen which had not been heated in an oxidising atmosphere.

The most probable explanation of the structure involves the assumption that ferrous oxide is soluble to a considerable extent in carbon-free iron at 950° C., so that when oxide is present at the surface it gradually diffuses into the body of the iron. At lower temperatures ferrous oxide is less soluble, and on cooling the excess separates as globules in the crystals. It is improbable, however, that the globules themselves are responsible for the ageing capacity of the iron. It appears to be more likely that some oxide remains in solution in the ferrite at ordinary temperatures, but is rendered less soluble by cold-work, so that cold-drawn iron containing oxide in solution increases in strength on ageing for the same reason as was assumed in the case of iron containing carbon.

The explanation here advanced to account for the exceptional magnitude of the age-hardening phenomenon in iron appears to be in accordance with the facts at present known, but further experimental work will be required before this explanation can be regarded as proved. It is thought that a careful study of the electrical resistivity of cold-worked iron may lead to valuable evidence, since the separation of either carbon or ferrous oxide from solution should lead to a decreased resistance.

REFERENCES.

(1) J. H. WHITELEY : " The Solution of Cementite in α-Iron and its Precipitation," *Journal of the Iron and Steel Institute*, 1927, No. II. pp. 293–303.

(2) T. E. ROONEY : " The Estimation of Oxygen in Pure Iron," *Journal of the Iron and Steel Institute*, 1924, No. II. pp. 122–128.

(3) F. S. TRITTON and D. HANSON : " Iron and Oxygen," *Journal of the Iron and Steel Institute*, 1924, No. II. pp. 90–121.

DISCUSSION.[1]

Mr. C. S. BURCH (Orpington) said he had been greatly interested in the paper and wished to express his thanks to the author, because the published results on the subject of cold-drawing were very meagre. Practical men were apt to keep the results they obtained to themselves, so that they owed a great debt of gratitude to anyone who was prepared to publish his researches.

The question of age-hardness was of very great interest. He noticed that the author had drawn the bars at a very low rate of speed, and he wondered if the age-hardening were affected by that low speed. According to some investigators, the speed of drawing exercised very little effect on the material drawn.[2]

The author did not give results on the influence of the age-hardening on the yield point and elongation, nor did he state what shape the test-pieces were ; the latter point made a considerable difference to the results.

He noticed that the pieces treated were of very small diameter, and that was done, he imagined, on the score of convenience, but the question of mass effect on larger bars might conceivably alter those results. Again, the programme of reduction which the author had adopted was unusual, and he (Mr. Burch) would like to ask if there were any reason for that choice.

Mr. G. GLENN (Sheffield) said he had read the paper with very great interest ; there were one or two points which he would like to mention, the first being in reference to the ageing of steel after cold-drawing. A piece of steel which was tested in December 1927 gave a test of 41·4 tons. It was kept in the laboratory at ordinary temperatures until last week, when it was tested again and pulled 48·4 tons. He might add that that result had been confirmed by other people as well. Both the tensile strength and elongation were altered, but the reduction of area had changed very little indeed. To bring that steel down it had to have a further heat treatment which would bring the tensile strength to 35 to 42 tons per sq. in., and it was found that after heat treatment no ageing would take place even after twelve months. With regard to the question of the speed of drawing and its effect on the tensile strength and elongation, that had no effect. Concerning the comparison of the reduction of area with the tensile strength shown in Fig. 1, he did not suggest that the figures were in any way wrong for the carbonless iron, but the 0·11 per cent. carbon iron

[1] At the Adjourned Meeting, Birmingham, Oct. 25, 1928.
[2] R. Giraud, *Revue de Métallurgie*, 1928, vol. xxv. pp. 175, 235, 347 ; H. Eicken and W. Heidenhain, *Stahl und Eisen*, 1924, vol. xliv. p. 1687.

should give values in accordance with one or other of the following formulæ :

$$MS = S + \frac{R}{2} \qquad (1)$$

or
$$MS = \left(S + \frac{R}{2}\right) + \left(\frac{x - 40}{4}\right) \qquad (2)$$

where MS = calculated tensile strength of the finished cold-worked steel in tons per sq. in. ;

S = tensile strength of the steel before cold-working ;

R = in equation (1) the percentage reduction of area or thickness which the steel had undergone or would receive by cold-work; in equation (2) 40 per cent. by cold-work (*i.e.* $R = 40$) ;

x = total percentage reduction of area or thickness received, or required to yield a given sought for tensile strength ;

4 = divisor for the ratio of the reduction by cold-work to the tensile strength.

Both equations were applicable to plain carbon steels. Equation (1) was used for calculating the tensile strengths of cold-worked steels which had received up to and including 40 per cent. reduction of area or thickness by some form of cold-working, either cold-drawing or cold-rolling of wires or strips respectively. Equation (2) was an extension of equation (1) for steels which had to receive more than 40 per cent. reduction by cold-work.

Taking the steel in column D, Table I., the tensile strength was 33·15 tons, with a reduction of 36 per cent. ; in his opinion the tensile strength should be in the region of 41 tons per sq. in. Going a little further down the table he came to the reduction of 86 per cent. ; in his opinion the tensile strength corresponding to that should be 54·65 tons instead of 46·4. In the carbon-free iron he suggested that that was due to the embrittling effect caused by oxides ; Fig. 5 showed that the carbon had been changed from the granular type to the pearlitic. In the paper there was one very important point, which Dr. Pfeil had brought out in a very able manner, namely, that carbon must be present to give additional strength ; but whether it were sorbitic or pearlitic he would not like to say. If a 0·80 per cent. carbon steel were annealed, a tensile strength of 35 to 40 tons per sq. in. would result ; if it were brought into the sorbitic condition the strength rose to the neighbourhood of 75 tons. He had no doubt that the estimation of the carbon in steel containing very low carbon, in the region of 0·02 per cent., was very difficult ; the best method, he found, was a direct combustion in oxygen followed by titration.

Dr. F. JOHNSON (Birmingham) said he felt sure that the members would recognise the value of the research work described in the paper. He was not able to contribute any data on the influence of ageing on the tensile strength of mild steel, but he could give some information on the influence of ageing on the hardness of cold-rolled Armco iron. The work was done in his department during the session 1921–22, but

there had been no real opportunity for repeating the experiments for
the purposes of publication.   The test-pieces examined were all of the
same thickness, the varying degrees of reduction being obtained by
commencing with pieces of different initial thicknesses, so that there
was no variable factor introduced in this respect.   The curves in Fig. A
showed that there was not only an age-hardening effect as the result
of cold-work, but that the effect appeared to be more pronounced the
greater the percentage reduction.   He had only learned of the author's
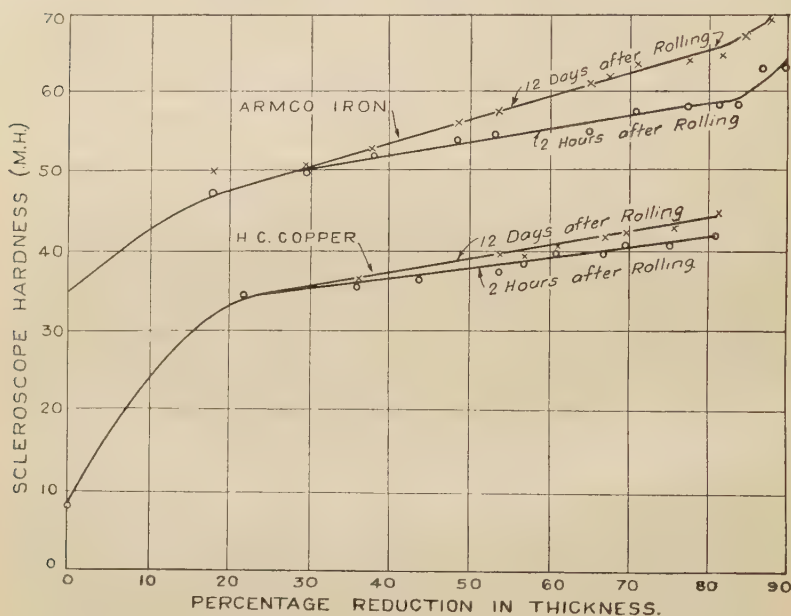
Fig. A.

theory by listening to his résumé of the paper, but he gathered that
the author was not himself convinced as to its finality.   It would be
wise, therefore, to regard it as tentative.   The curves shown in Fig. A,
representing a similar series of determinations of hardness on pro-
gressively cold-rolled copper, at first sight tended to indicate that
Dr. Pfeil's theory regarding a disturbance of the degree of solubility
by cold-work could not apply to other metals.   On further reflection,
however, he (Dr. Johnson) recollected that there was a small amount
of cuprous oxide in the copper specimens under reference.   Thus it
was possible that in that case also one could not altogether dispose of
the possibility of an infinitesimally small amount of oxide or even of
other impurity being present in solid solution.   Whilst not disproving
the author's theory, yet those results could not be regarded as helping

to confirm it. The inability of the author to obtain an increase in strength in the case of cold-worked carbon-free iron by ageing must be regarded as the strong point against any theory dependent on a disturbance of the arrangement of the atoms in the space lattice (resulting in slip interference), or upon the production of a temporarily mobile amorphous layer on planes of slip. He would conclude by expressing his great appreciation of the careful work done by the author and the very interesting results obtained.

Mr. E. ADAMSON (Sheffield) said that there was something interesting in the paper from the purely metallurgical side, which might be of assistance to the author as well as to young metallurgists generally. The author mentioned killed and semi-killed steels ; did he test them for oxygen before commencing his experiments, and if so did he find more oxygen in the semi-killed steel, which was a dangerous material ? That query was thrown out as a suggestion for a line of investigation ; if more oxygen were found in the semi-killed steel than in the killed, it might influence the author's views as to the presence of oxygen after heating.

He (Mr. Adamson) would also like to put forward another suggestion which might be worth following. Moissan had shown that the higher the temperature to which carbon was raised the more refractory it became to oxidising conditions. From his experience of the conditions of carbon in cast iron, he thought it might be that carbon in steel made from a rich kishy hematite might be slightly different from that found in steel made from a white basic pig iron.

Dr. R. H. GREAVES (Research Department, Woolwich) said that, as he understood it, Dr. Pfeil's view was that cold-work produced an unstable condition of supersaturation in the solid solution of carbon in α-iron, followed by precipitation of the carbide, which caused age-hardening. While he had a very great admiration for the experimental work which the author had carried out, it seemed to him that Dr. Pfeil had taken a narrow view of what was a wide and general phenomenon. It would be very difficult to explain the ageing after cold-work of some non-ferrous alloys in an analogous manner. There were non-ferrous alloys which could be cold-worked in the supersaturated condition and were then susceptible to ageing. In such alloys it might be possible to separate the hardening due to ageing after cold-work, and the hardening due to precipitation from solid solution. For example, certain copper-aluminium-nickel and copper-aluminium-manganese alloys hardened on heating to 200° C. after cold-work, but precipitation occurred only on heating at 450° C. or above.

Dr. Pfeil said the condition of the carbide was not of consequence. That might be so, but the amount of carbon affected the rate at which ageing proceeded. He was dealing with very low-carbon steels. If, however, a 0·7 per cent. carbon steel wire were tested after drawing

and again two or five years after the first test, it would be found that
the tensile strength had not altered; but if it were then heated to
200° C. and tested, there would be found a rise of 8 or 9 tons.   The
delay in, and magnitude of, that change were very difficult to explain
in the light of Dr. Pfeil's idea of the precipitation of a minute amount
of carbide from the α-iron present.   Did he mean the same explanation
to apply to steels of high-carbon contents ?

The question of age-hardening was bound up with the question
of the restoration of elastic properties.   Very pure iron recovered its
elastic properties after overstrain at a great rate, but the presence of
a little carbon would slow up the rate of recovery of pure iron very
much.   In drawing pure iron, enough heat might be developed in the
wire to cause ageing, and going slowly might not be a sufficient safe-
guard.   That should be taken into account in considering the results
obtained with that very pure iron.   Slow drawing was not the best
safeguard against heating, and it would be interesting to know how the
pure iron behaved after being drawn at a low temperature.   It was not
certain that pure iron would not show ageing if drawn at a lower tem-
perature than atmospheric.   Dr. Greaves said he much appreciated
the work done, but he thought that that theory (which held very nicely
for Dr. Pfeil's results as they stood) was unjustifiable when con-
sidered, as it must be, in relation to the general question of ageing
after cold-work.

Mr. W. H. WILKINSON (Leeds) asked if he understood Dr. Johnson
to say that in the cold-drawing of steel tubes it had been found that
the quicker the drawing operations were carried out the better the
product.   If that were so, it was just the contrary to what was found
in the cold-drawing of steel wire.   In that case it was found to be an
advantage to rest the material as far as possible between the passes.

With regard to Dr. Pfeil's paper, he mentioned that some time ago
he had made a few experiments to determine the effect of tempera-
ture on cold-drawn steel wire, and he had found that on heating to
about 400° C. there was a gradual increase in tensile strength.   That
increase appeared to be almost proportional to the amount of cold-
work given—that is, the greater the amount of cold-work, the greater
the increase in tensile strength.   The samples were of higher carbon
content than those used by Dr. Pfeil.

Mr. J. S. G. PRIMROSE (Manchester) desired to thank Dr. Pfeil
very much for his interesting paper, and the details of the valuable
work it contained.   It was a fact already well known to practical
workers that the strength of drawn steel increased with lapse of time,
irrespective of the speed of drawing.   The process of age-hardening
did not seem to stop at the end of the period named by the author, for
in using a similar mild steel in his investigations R. M. Brown had
proved there was an actual increase up to the end of one year after

drawing.[1] It was then claimed that as the plasticity of the metal diminished with ageing the hysteresis loop was closed up, and that reduction would probably indicate a longer life under fluctuating stress or a higher fatigue range for the material, provided it were sufficiently aged before use. In a subsequent paper [2] Brown showed that the stresses, which vary throughout the diameter of the wire, were not greatest at the surface, and might be in the nature of a compression at the core compared with tension near the surface. The increase in tensile strength due to ageing might possibly be due to a similar effect produced when cold-drawn steel was reheated to low temperatures. Grossmann and Snyder [3] showed that the tensile strength rose and the ductility decreased with progressive temperatures up to 315° C. The ductility increased beyond that point and the tensile strength fell, and their evidence supported the hypothesis that those phenomena originated in the amorphous metal produced by cold-work; something similar might occur in the process of ageing.

Mr. F. BLAKEY (Birmingham) said he had been much interested in Dr. Pfeil's paper, since his experience had been such as to supply instances where age-hardening might be presumed to be met with.

The phenomenon of age-hardening was made use of in everyday practice for gauges, which were kept for a considerable time before they were in a suitable state for use, and he thought that that same phenomenon applied to those high-carbon steels, such as razor blades, which cut very much better after they had had a rest. Actually, the steel was harder after it had remained in use for some time. He would like to know if Dr. Pfeil could give any explanation of that in high-carbon steels.

The CHAIRMAN (Mr. GEORGE HATTON, C.B.E., Member of Council) desired to ask the author if the increased tensile strength due to cold-drawing were retained in perpetuity, or was it gradually lost? A well-known form of bar largely used in the United States, and to some extent in this country, for ferro-concrete reinforcement was one, square in section, twisted cold to about one twist for every length of bar equal to eight or ten times the thickness throughout its entire length, which added several tons to its tensile strength. By that means a soft steel with a breaking strength of, say, 25 to 26 tons was raised to about 29 or 30 tons, and steels of higher initial tensile strength had their strengths increased in much the same ratio.

It was apparently evident that twisting in the cold, by compressing the molecules of the steel, produced a similar effect to that produced by cold-drawing.

[1] *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1925, vol. lxviii., Feb. 10, p. 362.

[2] *Ibid.*, 1928, vol. lxxi., Feb. 21, p. 495.

[3] *Transactions of the American Society for Steel Treating*, 1928, vol. xiii., Feb., p. 201.

The AUTHOR expressed his thanks to those who had contributed to the very interesting and helpful discussion. In reply to Mr. Burch, he said that the drawing was carried out with the aid of a Buckton tensile testing machine, partly because it allowed a very slow rate of drawing, and partly because it was desired to measure the load required to pull the wires through the dies. He pointed out that he was unfamiliar with the practical aspects of wire-drawing, and only made use of the process in order conveniently to obtain a series of samples representing closely-spaced stages of cold-work. For that reason the reductions employed were quite unlike those commercially employed. No figures were obtained for either elongation or yield point. The tensile tests were made on the full cross-section of the wires.

Mr. Glenn put forward formulæ for the calculation of the tensile strength of cold-drawn steel, but as those formulæ did not take into account the number of holes for a given reduction, he (Dr. Pfeil) did not think they could be applied generally, since it was well known that the reduction per hole had a very important influence on the strengthening effect of a given degree of total reduction. Drawing by small reductions, such as were employed for this work, would accordingly lead to low results as compared with commercial drawing operations. The presence of oxide in the metal caused an increase in the tensile strength, and its presence could not, therefore, be the cause of the discrepancy between Mr. Glenn's figures and his. The method suggested by Mr. Glenn for the estimation of carbon was unsuitable for this work, owing to its being impracticable to burn a sufficient weight of steel to give a quantity of CO_2 which could be estimated either by weighing as such or by titration. A preliminary concentration of the carbon was essential.

Dr. Johnson raised some very interesting points in connection with the age-hardening of Armco iron and of H.C. copper. He (Dr. Pfeil) was not convinced that copper age-hardened after cold-working. He had not any figures at the meeting, but would deal with the point in a written reply.

In reply to Mr. Adamson, he (Dr. Pfeil) said that the steel employed for the investigation was the best he could obtain for the purpose. So far as he knew it was impossible to obtain a commercial steel with 0·1 per cent. of carbon which was truly dead-melted. The steel employed for the investigation might be described as " rimming " steel; it contained a considerable amount of manganese and had been killed with aluminium. Similar results to those described in the paper had been obtained with a grade of steel known as " silicon soft." No estimation of oxygen had been made.

He thanked Dr. Greaves for his very helpful contribution, and thought he (Dr. Greaves) had summed up the situation very fairly. If it could be shown, as Dr. Greaves suggested might be the case, that carbon-free iron aged so rapidly after drawing that the increase in strength occurred before the tensile test could be made, then the

hypothesis of carbide precipitation collapsed. Dr. Greaves' suggestion that drawing and testing should be carried out at temperatures below atmospheric was valuable. It was known, however, that at very low temperatures the deformation of iron occurred by a mechanism different from the normal, for Neumann lamellæ were produced during deformation at very low temperatures. It might, therefore, be somewhat difficult to draw correct conclusions from such experiments. He (Dr. Pfeil) did not think it was desirable to compare the behaviour of steel with that of the non-ferrous alloys, for, so far as the evidence available indicated, pure iron was not subject to ageing, while there was some evidence to show that the non-ferrous metals were subject to the phenomenon. He (Dr. Pfeil) did not think that precipitation was the only possible cause of an increase in strength on ageing after cold-working; he thought it was the cause in the case of ferrite crystals at ordinary temperature, but he would not care to include the ferrite lamellæ in pearlite, nor would he explain the increase in strength of cold-worked iron and steel which occurred on annealing at 400° to 500° C. as due to the same phenomenon.

He was grateful to Mr. Primrose for the references to two papers by Brown; the second was published after the present work was completed, and he had not yet had an opportunity of reading it. He was under the impression that in Brown's earlier work he had cold-worked his specimens with the aid of one die only, obtaining different reductions by starting with annealed material of various sizes. In view of the very different experimental conditions it was impossible to correlate his results with those in the present paper. If the experimental results showing the absence of ageing in cold-drawn carbon-free iron were accepted as conclusive, it followed that the ageing effect in steel could not satisfactorily be explained on the basis of the amorphous phase.

In reply to Mr. Blakey, he said that his lack of experience of the behaviour of cold-drawn high-carbon steels made it impossible for him to offer any explanation of the points raised.

In reply to Mr. Hatton, he said that the longest period of ageing he had employed was nine months, after which period of time there was certainly no diminution of strength. Experience seemed to show that any method of cold-working steel increased its strength, and no doubt the increased strength of the twisted bars referred to was largely due to the internal changes occurring in the crystals during the twisting.

CORRESPONDENCE.

Mr. A. T. ADAM (Musselburgh) wrote: The author is to be congratulated on a research which has produced important results based on experimental evidence. His experiments appear to have been

conducted with such care that there is little room for doubting his conclusions. The work is a very interesting extension of the valuable research reported by Whiteley at the 1927 Autumn Meeting of the Institute in Glasgow on " The Solution of Cementite in α-Iron and its Precipitation."

The age-hardening of cold-worked steel has been attributed to many causes. The amorphous cement theory appears now to be quite out of fashion, having been displaced by the internal stress theory. I have never been able to see, however, how the release of internal stresses could explain all the phenomena associated with ageing or blueing. That such a condition as the lack of elasticity in freshly cold-worked metals is due mainly to the internal stresses is doubtless well established, but though the removal of those stresses by ageing or mild blueing probably explains the recovery of elasticity, it cannot very well explain the increase in tensile strength or hardness.

Is it not probable, however, that the rejection of the dissolved carbon discovered by the author's experiments and the release of internal stresses have some relation to one another ? This point could be settled by an extension of the author's experiments to include an investigation of the elastic properties of the carbon-free iron in the cold-worked and aged conditions respectively.

In this connection it may be of interest to mention that in conducting some tests on cold-drawn Armco iron along with Mr. F. S. Merrils some years ago, I was rather surprised to find that some of the samples failed to give the typical stress-strain diagram of freshly drawn material, and were apparently unaffected by ageing or mild blueing. This was at first attributed to some error in testing, but the test was repeated with the same result. No great notice was taken of the matter at the time, but it was considered not improbable that the elastic recovery took place much more rapidly in the almost carbon-free iron. This conclusion is, I believe, referred to in Merrils' paper,[1] although he does not go so far as to connect the immediate elastic recovery with the absence of dissolved carbon. I cannot say what was the exact carbon content of the iron in question. By ordinary combustion estimation it was somewhere about 0·03 per cent., but this cannot, of course, be considered an accurate figure.

In view, however, of Whiteley's experiments, it seems to me that the absence of age-hardening discovered by Dr. Pfeil in iron containing less than 0·0025 per cent. carbon should also be evident in the iron containing even as much as 0·03 per cent. carbon, when such a specimen has been reheated to a temperature in the neighbourhood of 680° C. several times as this sample had been during the process of reduction, since the dissolved carbon may have been distributed to the grain boundaries, as shown by Whiteley.

[1] F. S. Merrils, " Studies in the Fatigue of Metals," *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1924, vol. xiii. pp. 83–128.

Connecting the work of Whiteley with that of Dr. Pfeil, is it not suggested that the whole process of the divorce of pearlite, which is so greatly facilitated by cold-working, is associated with the solution and precipitation of the carbon, and may it not also be suggested that this process is associated also with the internal stresses set up by cold-working ?

The existence of internal stresses in cold-worked steel is of great practical importance, and has formed the subject of a recent investigation by Brown,[1] in so far as the use of bright drawn bar for engineering structures is concerned. It is of even greater importance, in my opinion, in connection with the properties of rope-wire. For reasons too lengthy for inclusion here, I believe the peculiar toughness or durability of rope-wire is very largely due to the state of internal stress in such wire.

I do not know whether the stress conditions due to cold-work can be associated with the release of dissolved carbon or not, but I should be extremely interested to have Dr. Pfeil's views on this point. It would indeed be strange if the toughness of rope-wire were found to depend indirectly on the small percentage of carbon dissolved in the iron.

Mr. J. H. WHITELEY (Consett) wrote : In my opinion, no conclusive evidence is advanced in this interesting paper to show that carbon plays any part in the ageing effect. The facts given by the author suggest, rather, that oxygen alone is responsible, for it is practically certain that the sample of steel used would contain some oxide, and by the time all the carbon had been removed by hydrogen treatment most of the oxygen had probably been eliminated too. At any rate, this point does not seem to have been sufficiently considered. Notwithstanding the slow rate of deoxidation in hydrogen, enough might be removed in six weeks at 750° C. to account for the absence of any subsequent ageing. A comparison of Figs. 3 and 4 tends to support this contention, for in Fig. 3 the ferrite appears to be almost free from inclusions. From careful observations, I have for a long time suspected that oxide exists in the ferrite grains as almost sub-microscopic particles, and it may well be that it is the slow rearrangement of such minute particles, after cold-working, which gives rise to the results obtained by the author. In this connection I might add that it would be interesting to ascertain the way in which the hardness increases. Is the increase gradual, or does it occur quickly after a certain period has elapsed ?

The AUTHOR wrote, in further reply to Dr. Johnson, that the very different conditions under which Dr. Johnson had cold-worked his

[1] R. M. Brown, " An Investigation into Some Effects of Cold-Drawing on the Strength and Endurance of Mild Steel," *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1928, vol. lxxi., Feb. 21, p. 495.

specimens of Armco iron and had measured the age-hardening effect made it rather difficult to correlate the two sets of tests. It seemed probable that Dr. Johnson's scleroscope measurements might be more closely related to the recovery of elastic properties than to an increase in tensile strength. It was also possible that the complete absence of ageing represented by one of Dr. Johnson's points and the general trend of his curve for Armco iron were due to twelve days being insufficient for the development of a marked ageing effect when the cold-work was not severe. During his work he (Dr. Pfeil) had noticed a tendency for the development of the maximum ageing effect to be slower in the less severely worked wires. He was interested to note the very small degrees of ageing found by Dr. Johnson in the case of cold-rolled H.C. copper. He (Dr. Pfeil) had carried out some experiments on the ageing of H.C. copper wires, and had come to the conclusion that no increase in tensile strength occurred either by ageing or by heat treatment after cold-rolling. The same conclusion was recorded by Alkins in his research on " The Effect of Progressive Cold-Work upon the Tensile Properties of Copper." [1]

After considering the suggestion made by Dr. Greaves that carbon-free iron aged before the tensile tests were made, he had come to the conclusion that that was improbable. The results given in the paper indicated that the ageing effect was independent of the degree of cold-work and varied from 2 to 3 tons per sq. in. If the presence of carbon were not the cause of the ageing but only affected the rate of ageing, it would be reasonable to suppose that the figures given for carbon-free iron were $2\frac{1}{2}$ tons too high. A comparison of the amended figures with the unaged results for iron containing very small amounts of carbon showed that so small an amount of carbon as $0\cdot003$ per cent. would, on that assumption, be the cause of an increase in strength of no less than $4\frac{1}{4}$ tons per sq. in. It was difficult to believe that $0\cdot003$ per cent. of carbon, either in solution in the ferrite or present as cementite patches, could account for an increase in strength of 15 per cent. The comparison was set out in the following table :

| Reduction. % | Carbon-Free Iron. Tensile Strength. | | Iron containing Carbon. | | Difference between A and B. Tons per sq. in. |
	Actual. Tons per sq. in.	Less $2\frac{1}{2}$ tons per sq. in. A. Tons per sq. in.	Immediate Tensile Strength, B. Tons per sq. in.	Carbon. %	
0	$18\cdot40$	...	$19\cdot25$	$0\cdot003$	...
$22\cdot8$	$24\cdot65$	$22\cdot15$	$26\cdot35$	$0\cdot0025$	$4\cdot20$
$44\cdot0$	$27\cdot80$	$25\cdot30$	$29\cdot65$	$0\cdot006$	$4\cdot35$
$52\cdot8$	$29\cdot00$	$26\cdot50$	$30\cdot71$	$0\cdot003$	$4\cdot21$
$61\cdot2$	$30\cdot20$	$27\cdot70$	$31\cdot95$	$0\cdot003$	$4\cdot25$

[1] *Journal of the Institute of Metals,* 1918, No. 2, pp. 33–46.

In that connection it might be of interest to add that the tensile strength of annealed iron rose fairly steadily with increasing carbon as follows :

Carbon. %	Tensile Strength. Tons per sq. in.
Zero	18·4
0·001	18·6
0·003	19·25
0·0045	19·55
0·010	19·95
0·011	20·0
0·014	20·3

There was no indication here that small quantities of carbon had any extraordinary strengthening effect.

He (Dr. Pfeil) was not able to agree with Mr. Adam that the removal of internal stresses could not explain an increase in tensile strength, for if a cold-drawn wire had part of the cross-section in tension and the remainder in compression, then the strength of the part already in tension would be exceeded at a lower external load than would other-wise be required, and complete fracture would quickly follow. He thought, however, that the release of internal stress was an entirely different problem from that considered in the present paper. There was no reason to suppose that the presence of a *minute* quantity of carbon would cause a large alteration in the internal stress in the cold-drawn material and thus result in the different behaviour of the two types of material on ageing. It was quite certain that, like the steels, carbon-free iron after cold-working was subject to changes in properties on annealing at about 400° to 500° C., the increase in hardness by such treatment being readily detected. He thought that those changes were totally different from the phenomenon discussed in the paper.

Mr. Adam did not appear to have appreciated that the ageing was suggested to be due only to such carbon as was in solution in the ferrite at the ordinary temperature. The figure 0·03 per cent. referred to the solubility of carbon in ferrite at 700° C., and Whiteley had shown that nearly all of that was deposited on cooling. The carbide so deposited was, however, in a sufficiently massive form to be seen under the microscope, and not in the highly dispersed state required to cause an important increase in tensile strength.

He would not care to suggest that the deposition of carbon from solution in ferrite after cold-working was a matter of any moment in such material as rope-wire. Even if the 2 to 3 tons increase in strength were developed it would be negligible.

It was important to avoid confusing the strengthening effect pro-duced by cold-working with such changes as those due to the release of internal stresses and those discussed in the present paper.

He could assure Mr. Whiteley that, while it was true that little was said in the paper about the possibility of oxygen being entirely

1928—ii.   O

responsible for the ageing effect, it was not because the possibility had been overlooked. It was very difficult to be sure of what was happening to the oxygen in iron and steel in the absence of quantitative estimations, but, from the results recorded in the paper and a very much larger number of results not recorded, it was clear that the disappearance of the ageing effect exactly coincided with the disappearance of the carbon. The question then arose of how probable it was that the last traces of oxygen would be removed at the same time as the last traces of carbon. In view of the varying temperatures employed for the hydrogen decarburisation, it seemed very improbable that the disappearance of the last traces of oxygen would coincide with the removal of the last traces of carbon, and as a consequence that aspect of the problem raised by Mr. Whiteley was not dealt with. As regards the relative quantity of inclusions visible in Figs. 3 and 4, no great weight must be attached to the point, for, as was almost universal in very low-carbon steels, the amount of inclusions varied considerably over the cross-section of the rods, being considerably greater in the centre portion of the section.

He regretted that the study of the corresponding changes in hardness or ageing, although in hand, had not progressed sufficiently for conclusions to be drawn with any certainty.

SOME PROPERTIES OF COLD-DRAWN AND OF HEAT-TREATED STEEL WIRE.*

By S. H. REES, B.Sc.

(RESEARCH DEPARTMENT, WOOLWICH).

I.—COLD-DRAWN STEEL WIRE.

THE effect of heat treatment on cold-drawn carbon steel has been investigated by Goerens, Adam, Aitchison, and others.[1, 2, 3] Some similar work carried out on cold-drawn alloy steel wire is described here. The wire was obtained from Messrs. Samuel Fox & Co., Ltd., Stocksbridge Works, near Sheffield, to whom the author wishes to express his thanks for their readiness to assist in this experimental work. The material employed was chromium-vanadium steel, cold-drawn from $0 \cdot 375 \times 0 \cdot 212$ in. rod to $0 \cdot 25 \times 0 \cdot 06$ in. wire in six holes; it had the following composition :

Carbon. %	Silicon. %	Manganese. %	Sulphur. %	Phosphorus. %	Chromium. %	Vanadium. %
0·42	0·24	0·56	0·041	0·026	1·11	0·20

The Effect of Low-Temperature Heat Treatment on the Mechanical Properties.

The effect of various temperatures of heating was investigated. The treatment was carried out at temperatures up to 100° C. in water, from 100° C. to 250° C. in oil, and above that temperature in a salt bath. Tensile tests were made in a 2·5-ton Amsler machine, extensions being measured by means of a lever extensometer actuating an Ames dial (Berry strain gauge). The instrument was calibrated against the Ewing extensometer, and readings could be taken to 0·00004 in. on a 2-in. length. No extensions could be measured for loads below 15 tons per sq. in., as it was found necessary to apply a small load to eliminate the bend of the wire.

TABLE I.—*Tensile Tests. Effect of Temperature of Heat Treatment on Cold-Drawn Chromium-Vanadium Steel Wire.* (*Carbon* 0·42, *Chromium* 1·11, *Vanadium* 0·20 *per cent.*)

Temperature of Heating (1 hr.). ° C.	Limit of Proportionality (Berry Strain Gauge). Tons per sq. in.	Yield Point. Tons per sq. in.	Maximum Load. Tons per sq. in.	Elongation on 2 in. %	Brinell Hardness Number.
As drawn	45	90·0	107·0	2·5	418
100	46	95·0	109·3	1·0	415
200	74	102·3	111·3	3·0	428
250	86	110·6	114·2	2·0	457
300	88	108·3	110·8	4·0	448
400	80	101·6	102·6	4·0	444
450	78	95·3	97·3	5·5	426
500	73	89·6	90·1	6·0	408
550	69	86·0	86·1	6·0	392
600	41	53·6	53·9	13·0	268

By Mirror Extensometer.	As Drawn.	After Treatment at—					
		100° C.	200° C.	300° C.	400° C.	500° C.	600° C.
Limit of proportionality. Tons per sq. in.	26	32	43	64	61	56	44
Load at which permanent set commences. Tons per sq. in.	37	44	53	74	68	61	...

The yield point was taken as the load giving a total extension of 0·02 in. on 2 in., equivalent to a permanent extension of about 0·25 per cent. when the yield point was in the vicinity of 100 tons per sq. in.

The results given in Table I. and shown in Fig. 1 are averages of two or more tests. Restoration of elasticity at atmospheric temperature is most complete after heating for 1 hr. at about 300° C., but the tensile strength begins to fall after treatment for 1 hr. at temperatures above 250° C.

Since departure from proportionality in cold-drawn steel is very gradual, tests were also made in a 3-ton Avery machine, extensions being measured by means of a mirror extensometer. With this instrument readings could be taken to 0·000002 in. on a gauge length of 0·7 in. (which corresponds to 0·0000057 in. on a gauge length of 2 in.).

The values obtained for the limit of proportionality (except after heat treatment at 600° C.) were, as would be expected, considerably lower than before, owing to the increased sensitivity of the extensometer used.   Permanent set did not appear until the limit of proportionality as measured by the mirror extensometer had been exceeded (Table I.).   At loads recorded for the
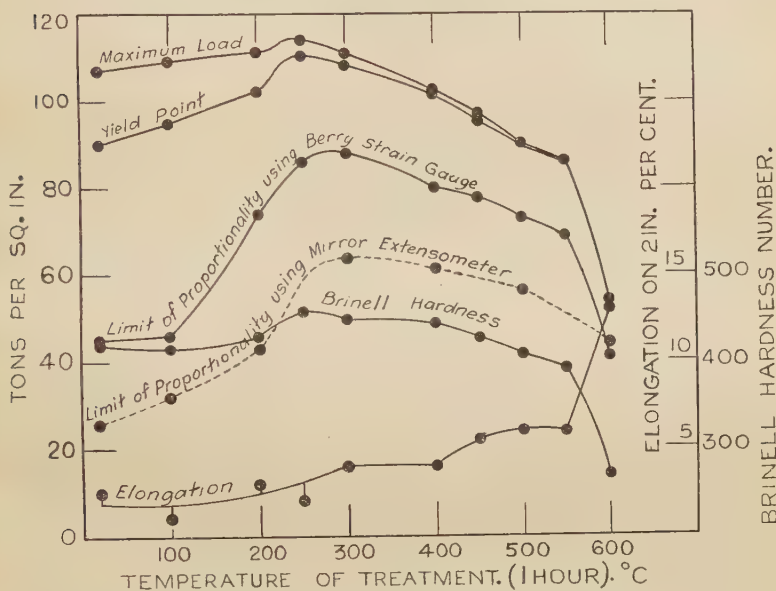
Fig. 1.—The Effect of Heat Treatment on the Mechanical Properties of Cold-Drawn Chromium-Vanadium Steel Wire.

commencement of permanent set, the permanent extension of the test-piece did not exceed 10^{-5} in.

The effect of temperature on the limit of proportionality as shown by both series of tests was relatively the same, the maximum value being reached after treatment at 300° C.   After treatment at 600° C., owing to more rapid departure from proportionality, practically the same values were obtained with both extensometers.

A comparison of the two series is given by curves in Fig. 1.

A corresponding diagram for cold-drawn carbon steel wire is reproduced in Fig. 2.   It may be assumed that the limits of

proportionality shown in Fig. 2 would be similarly reduced by more accurate measurements.

Brinell hardness tests made with a ball 2 mm. in diameter and a load of 120 kg. showed initial hardening on low-temperature treatment, and the hardness number did not fall to its original value until treatment for 1 hr. at 450° C. had been applied.
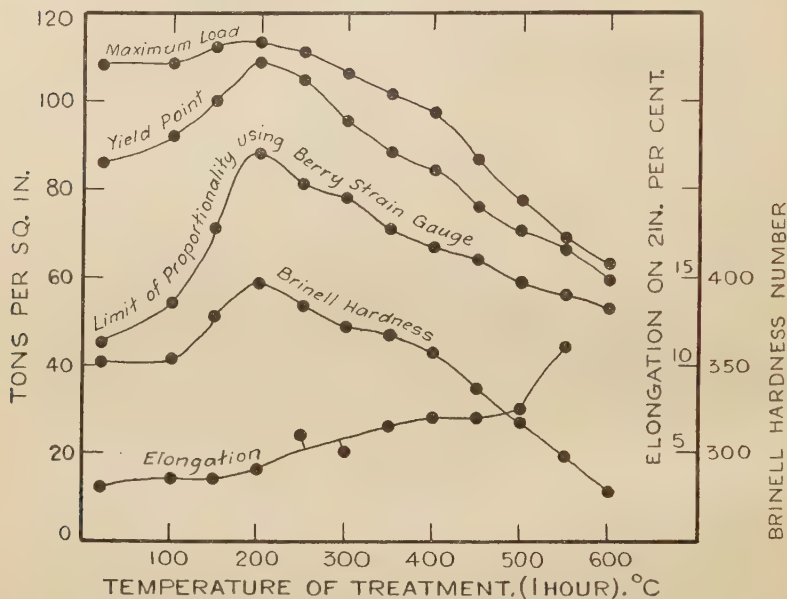
FIG. 2.—The Effect of Heat Treatment on the Mechanical
Properties of Cold-Drawn Carbon Steel Wire.

As in the case of carbon steel wire,[3] the ratio of maximum load to Brinell hardness number, raised considerably by cold-drawing, was reduced progressively by the subsequent treatment. It fell from 0·26 to 0·20 as the temperature of treatment was raised to 600° C. Heating to 750° C. was necessary to soften the wire completely (Brinell hardness number 196).

The Effect of Low-Temperature Heat Treatment
on the Microstructure.

The changes in microstructure were characteristic of severely cold-drawn steel (Figs. 3 to 6, Plates XXXVIII. and XXXIX.).

The wire as drawn showed highly distorted ferrite and sorbitic pearlite drawn out in a longitudinal direction (Fig. 3). There was no change of microstructure after treatment at temperatures up to 450° C. Treatments at higher temperatures led progressively to slight coalescence of the carbide (Figs. 4 and 5), but this was much less pronounced than in carbon steel. Heating into the critical range (750° C.) and cooling in air gave troostite and sorbite (Fig. 6), and heating to higher temperatures (900° C.) resulted in a structure of acicular ferrite and sorbitic pearlite.

The Effect of Low-Temperature Heat Treatment on the Dimensions of the Wire.

The effect of heating the cold-drawn material is in general to increase the density, which has been slightly diminished by cold-work ; but the change of density is dependent on the amount of cold-drawing which has taken place.[1, 4] In carbon steel most of the increase occurs after heating at temperatures of 500° C. and above ; in chromium-vanadium steel, as indicated by the results given in Table II., the increase occurs principally after heating at 600° C. and above. The increase in density after reheating at 750° C. was 0·026, or 0·33 per cent.

TABLE II.—*Dimensional Changes Due to Heat Treatment.*

Temperature of Heating (1 hr.). ° C.	Chromium-Vanadium Steel Wire.			Carbon Steel Wire.*	
	Density.	Increase in Density. %	Increase in Length. %	Increase in Density. %	Increase in Length. %
As drawn	7·813	...	...	...	...
200	7·814	0·01	0·02	...	0·05
250	7·816	0·04	0·035	0·08	0·09
350	7·822	0·11	0·07	0·10	0·12
450	7·831	0·23	0·11	0·14	0·13
550	7·827	0·18	0·13	0·17	0·12
650	7·835	0·28	0·17	0·22	0·11
750	7·839	0·33	...	...	...

* *R.D. Report*, No. 60, p. 25.[3]

The increase in density (decrease in volume) was, however, accompanied by an increase in length (Table II.). The maximum

extension observed on heating at temperatures below Ac_1 was 0·17 per cent. Some extension may be accounted for on the assumption that the internal tensile stresses are greater in magnitude, but act over a smaller area of cross-section than the compressive stresses. Heat treatment causes a greater reduction of the higher stress (tension), and in the resulting redistribution of the internal stress the specimen will extend. It has been shown that this effect actually occurred in carbon steel wire, but that it was insufficient to account for more than about half of the observed total change of length.[3] It appears probable that grain-growth after recrystallisation in this severely cold-worked material is directional, and proceeds more rapidly in the longitudinal than in the transverse direction.

The Effect of Preliminary Low-Temperature Heat Treatment on the Behaviour of the Wire under Stress at Temperatures above Atmospheric.

The behaviour of both untreated and treated chromium-vanadium steel wire under stress at temperatures above atmospheric has been investigated :

(1) By determining the permanent set in wire bent on formers of different radii and heated to various temperatures.

(2) By determining the permanent set in wire heated to various temperatures under different loads applied in a tensile testing machine.

Permanent Set on Bending.—The wire was bent on formers of different radii and held in position while the required treatment was applied. On releasing the wire it took up a form intermediate between its original straightness and the arc to which it was constrained during treatment. The curvature of the wire after treatment gave a measure of the permanent set.

Deductions as to the loss of tension in the outer fibres of the stressed wire can be made from these results in the manner described by Moore and Beckinsale.[5] If a flat strip of uniform thickness t is bent elastically to form the arc of a circle (radius r), the tension at the outer surface is equal to $\dfrac{Et}{2r}$, where E is Young's modulus. If the wire is originally not quite straight but has an

initial radius of curvature r_1, the tension at the outer surface is $\dfrac{Et}{2}\left(\dfrac{1}{r} - \dfrac{1}{r_1}\right)$.

If, while the specimen is held with a radius of curvature r, a treatment which will reduce the stress is applied, and the strip released after cooling, it will assume a radius of curvature r_2, which is intermediate between r and r_1. The remaining stress after treatment and before release $= \dfrac{Et}{2}\left(\dfrac{1}{r} - \dfrac{1}{r_2}\right)$, and the loss of tension at the surface $= \dfrac{Et}{2}\left(\dfrac{1}{r_2} - \dfrac{1}{r_1}\right)$.

For small values of r the calculated initial stress at the outer surface exceeds the elastic limit of the steel. These stresses are therefore never actually attained, but the calculated values are recorded to give an idea of the relative magnitudes of the stresses applied.

Results of tests are given in Tables III. and IV., where loss of tension is expressed as a percentage of the initial stress. The loss of tension which occurs is rapid at first, and in most cases, when the total loss of tension is small, the stress remains fairly constant after 1 hr. The approximately constant tension attained after 2 hr. is used in calculating the loss of tension given in the tables.

Permanent Set on Loading in Tension.—A length of about 30 in. of wire was passed through a small-bore electric tube furnace and held in the grips of a 2·5-tons vertical Amsler testing machine. The furnace was arranged to heat the lower part of the wire over a length of 6 in., and the temperature was read by means of a thermocouple attached to the wire. The furnace could at any moment be raised to the upper part of the wire and secured to the upper shackles of the machine. While the furnace was in this position a test was started by applying a load of 15 tons per sq. in. to straighten the wire. A length of 4 in. was marked off by means of a scriber from a fixed point on the lower part of the wire. The load was increased to the required amount (say, 50 tons per sq. in.). The furnace was lowered and heated slowly to the required temperature, the load being kept constant all the time. After 10 minutes at the required temperature the furnace was raised and the lower part of the wire allowed to cool, the load still being

TABLE III.—Carbon Steel Wire. (R.D. Report, No. 60, p. 27.[3]) Loss of Tension (expressed as Percentage of Calculated Initial Tension) on Heating to Various Temperatures. Effect of Preliminary Treatment, Initial Tension, and Temperature.

Condition of Wire.	As Drawn.			After Heating for 1 hr. at—																	
				100° C.			200° C.			300° C.			400° C.			500° C.			650° C.		
Average Calculated Initial Tension. Tons per sq. in.	77.	54.	32.	78.	54.	33.	79.	56.	35.	79.	57.	34.	80.	56.	34.	79.	57.	35.	80.	57.	35.
Loss of tension at various temperatures																					
Atmospheric	13	2	Nil	10	2	Nil	3	Nil	Nil	Nil	Nil	Nil	3	Nil	Nil	6	2	Nil	17	2	3
100° C.	23	14	8	24	9	7	7	2	Nil	6	5	Nil	5	Nil	Nil	8	4	Nil	17	7	4
150° C.	34	24	16	31	21	16	12	7	4	13	9	Nil	14	2	4	15	2	Nil	36	15	4
200° C.	37	25	16	34	24	16	26	16	14	17		4	14	5	3	19	5	Nil	36*	23	4
250° C.	44	31	29	47	35	31	38	31	22	24	13	4	19	7	Nil	22	9	Nil	43	29	15
300° C.	55	45	39	53	44	35	49	42	29	47	32	22	34	18	11	32	18	7	47	32	15

* The calculated initial tension was 73 tons per sq. in. This figure was not used in calculating the average tension at the head of the column.

Note.—The tensions could not be estimated within 1·5 tons per sq. in.

TABLE IV.—*Chromium-Vanadium Steel Wire. Loss of Tension (expressed as Percentage of Calculated Initial Tension) on Heating to Various Temperatures. Effect of Preliminary Treatment, Initial Tension, and Temperature.*

Condition of Wire.	As Drawn.			After Heating for 1 hr. at—																		
				100° C.			200° C.			300° C.			400° C.			500° C.			600° C.		
Average Calculated Initial Tension. Tons per sq. in.	80.	52.	33.	82.	55.	36.	82.	55.	35.	82.	55.	35.	82.	54.	35.	83.	55.	35.	81.	52.	34.
Atmospheric	5	2	Nil	5	2	Nil	3	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	2	Nil	Nil	8	Nil	Nil
100° C.	17	14	11	15	9	11	8	5	4	2	Nil	Nil	2	Nil	Nil	3	Nil	Nil	20	2	Nil
150° C.	27	23	19	26	21	21	12	7	8	5	2	Nil	2	Nil	Nil	5	Nil	Nil	21	5	Nil
200° C.	33	29	23	32	27	25	20	14	8	8	2	Nil	5	Nil	Nil	6	Nil	Nil	34	9	4
250° C.	37	33	28	37	33	28	26	21	18	9	2	4	6	Nil	Nil	8	2	Nil	39	19	8
300° C.	43	36	38	42	37	37	35	30	29	20	16	14	9	5	4	11	7	4	39	22	15

Note.—The tensions could not be estimated within 1·5 tons per sq. in.

TABLE V.—Cold-Drawn Chromium-Vanadium Steel Wire. Effect of Preliminary Treatment on Permanent Set at Various Temperatures.

Condition of Wire.	Load. Tons per sq. in.	Percentage Permanent Set when Loaded at—										
		Atmos. Temp.	100° C.	150° C.	200° C.	250° C.	300° C.	350° C.	400° C.	450° C.	500° C.	550° C.
As drawn	20	Nil	0·02	0·04	0·06	0·10	0·13	0·17	0·23	0·30	0·58	1·40
	35	Nil	0·03	0·07	0·13	0·18	0·22	0·26	0·38	0·62	1·55	...
	50	0·06	0·09	0·15	0·21	0·28	0·35	0·45	0·66	1·32	...	...
	65	0·06	0·13	0·22	0·34	0·46	0·57	0·75	1·50	...	...	...
After heating for 1 hr. at— 100° C.	20	0·02	0·03	...	0·06	0·09	0·12	0·16	0·22	0·30	0·46	1·25
	35	0·02	0·04	0·08	0·12	0·17	0·20	0·26	0·36	0·56	1·40	...
	50	0·02	0·07	0·12	0·19	0·30	0·33	0·40	0·60	1·28	...	...
	65	0·05	0·11	0·20	0·33	0·43	0·53	0·68	1·40	...	...	...
200° C.	20	Nil	Nil	...	0·02	0·05	0·08	0·13	0·20	0·30	0·42	1·00
	35	Nil	Nil	...	0·02	0·07	0·12	0·18	0·28	0·50	1·70	...
	50	0·02	0·02	0·08	0·12	0·15	0·23	0·29	0·53	1·10	...	...
	65	0·02	0·07	0·10	0·18	0·28	0·40	0·60	1·33	...	...	...
300° C.	20	Nil	Nil	Nil	Nil	Nil	Nil	0·06	0·10	0·20	0·50	1·03
	35	Nil	Nil	Nil	Nil	Nil	0·02	0·10	0·20	0·47	1·20	...
	50	Nil	0·01	0·02	0·03	0·05	0·10	0·20	0·40	1·12	...	...
	65	0·02	0·02	0·05	0·10	0·12	0·22	0·42	0·98	...	...	...
	80	...	...	...	...	...	...	...	...	...	...	...
	90	...	...	...	...	...	...	...	...	...	...	...
400° C.	20	Nil	Nil	Nil	Nil	Nil	Nil	0·02	0·03	0·13	0·30	0·90
	35	Nil	Nil	Nil	Nil	Nil	0·01	0·03	0·11	0·30	0·95	...
	50	Nil	Nil	Nil	0·02	0·03	0·05	0·10	0·26	0·88	...	...
	65	Nil	0·03	Nil	0·08	0·12	0·19	0·32	1·00	...	...	...
	80	0·03	...	...	...	...	...	...	...	...	...	...
	90	0·06	...	...	...	...	...	...	...	...	...	...
450° C.	20	Nil	Nil	Nil	Nil	Nil	Nil	0·01	0·02	0·10	0·25	0·80
	35	Nil	Nil	Nil	Nil	Nil	0·02	0·03	0·08	0·32	0·95	...
	50	Nil	Nil	Nil	0·02	0·04	0·05	0·10	0·28	1·03	...	...
	65	Nil	0·03	0·05	0·10	0·14	0·22	0·44	1·75	...	...	...
	80	0·03	...	...	...	...	...	...	...	...	...	...
500° C.	20	Nil	Nil	Nil	Nil	Nil	Nil	0·01	0·03	0·12	0·23	0·75
	35	Nil	Nil	Nil	Nil	...	0·02	0·05	0·10	0·34	1·20	...
	50	Nil	Nil	...	0·02	0·03	0·05	0·10	0·25	1·25	...	...
	65	Nil	0·03	0·05	0·10	0·15	0·22	0·43	1·87	...	...	...
	80	0·06	...	...	...	...	...	...	...	...	...	...

kept constant. When atmospheric temperature was reached the load was reduced to 15 tons per sq. in., a line scribed at 4-in. radius, and the distance between the two lines measured by means of a portable microscope with an eye-piece scale. Results are given in Table V.

Tests were made to determine whether creep occurred under prolonged loading. At temperatures producing rapid restoration of elasticity, and under stresses giving small permanent set, the maximum extension was attained very rapidly, and no subsequent creep was detected. The strain-hardening and the elastic restoration were sufficiently rapid to arrest further extension under stress. This certainly applied to temperatures between 200° and 500° C. and to the permanent set of 0.03 per cent. on which conclusions were based.

TABLE VI.—*Effect of Preliminary Treatment on Permanent Set at Elevated Temperatures.*

Condition of Wire.	Load giving Permanent Set of 0.03% at—				
	Atmos. Temp.	100° C.	200° C.	250° C.	300° C.
*Cold-Drawn Carbon Steel Wire.**					
	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.
As drawn . .	38	30	Nil	Nil	Nil
Heated 1 hr. at—					
200° C.	75	60	35	Nil	Nil
300° C.	70	65	45	35	20
400° C.	65	50	35	30	20
500° C.	50	35	25	20	15
Cold-Drawn Chromium-Vanadium Steel Wire.					
As drawn . .	40	30	5	Nil	Nil
Heated 1 hr. at—					
200° C.	70	55	35	Nil	Nil
300° C.	90	70	50	45	40
400° C.	80	65	55	50	45
450° C.	80	65	55	45	45
500° C.	75	65	55	50	40

* *R.D. Report, No.* 60, p. 31.[3]

A comparison is given in Table VI. of the tensions supported (subject to a permanent set of 0.03 per cent., which is equivalent to a loss of tension of 4 tons per sq. in.) at various temperatures

by chromium-vanadium and by carbon steel wire before and after treatment.

II.—Hardened and Tempered Steel Wire.

The use of hardened and tempered steel wire has been recommended when material is required which will behave elastically under variations of stress and temperature.[2]

Tests have been made on similar lines to those described above, with the object of comparing the behaviour of hardened and tempered wires of chromium-vanadium steel and of carbon steel with one another, and with the same materials in the cold-drawn condition.

Chromium-vanadium steel wire, $0 \cdot 25 \times 0 \cdot 06$ in. in section and of the following composition, was employed :

Carbon. %	Silicon. %	Manganese. %	Sulphur. %	Phosphorus. %	Chromium. %	Vanadium. %
0·43	0·22	0·66	0·043	0·042	0·93	0·23

The wire was oil-hardened from 900° C., and tempered by running between hot plates at an approximate temperature of 525° C., each portion being exposed to the maximum temperature of the plate for about 15 seconds.

The mechanical properties of the steel after this treatment, and also the properties after retempering for 1 hr. at 300°, 350°, 400°, and 500° C., are given in Table VII. :

TABLE VII.—*Tensile Tests.   Mechanical Properties of Oil-Hardened and Tempered Wire.*

Wire and Treatment.	Limit of Proportionality. Tons per sq. in.	Yield Point. Tons per sq. in.	Maximum Load. Tons per sq. in.	Elongation on 2 in. %
Chromium-Vanadium Steel Wire.				
After original treatment *	71	89·9	98·7	6·0
Retempered at 300° C.	73	90·7	98·1	6·0
,, ,, 350° C.	72	90·0	95·9	5·5
,, ,, 400° C.	75	89·5	95·3	6·0
,, ,, 500° C.	66	75·8	79·7	7·0
Carbon Steel Wire, Oil-Hardened from 900° C.				
Tempered at 400° C.	48	84·3	89·8	4·0
,, ,, 500° C.	51	64·6	72·3	8·0

* Oil-hardened from 900° C. ; tempered by running between hot plates.

TABLE VIII.—*Oil-Hardened and Tempered Chromium-Vanadium Steel Wire. Permanent Set at Various Temperatures after Original Treatment and after Retempering.*

Treatment.	Load. Tons per sq. in.	Percentage Permanent Set when Loaded at—										
		Atmos. Temp.	100° C.	150° C.	200° C.	250° C.	300° C.	350° C.	400° C.	450° C.	500° C.	550° C.
After original treatment	20	Nil	Nil	Nil	Nil	0·02	0·04	0·07	0·11	0·25	0·60	2·15
	35	Nil	Nil	...	0·02	0·05	0·10	0·17	0·38	0·78	2·90	...
	50	Nil	Nil	...	0·07	0·11	0·20	0·31	0·61	2·33	...	...
	65	Nil	0·06	0·12	0·22	0·34	0·58	1·03	...	...	...	...
	80	0·08	0·24	0·41	0·64	1·10	2·40	...	...	...	...	...
Retempered at— 350° C.	35	Nil	Nil	...	0·02	0·03	0·05	0·10	0·28	0·88	4·15	...
	50	Nil	0·02	0·03	0·08	0·10	0·14	0·24	0·55	3·50	...	...
400° C.	35	Nil	Nil	...	Nil	0·02	0·03	0·05	0·16	0·46	2·80	...
	50	Nil	Nil	0·03	0·05	0·07	0·09	0·15	0·44	1·84	...	...
500° C.	35	Nil	Nil	...	Nil	0·02	0·03	0·05	0·10	0·35	1·93	...
	50	Nil	Nil	0·03	0·08	0·10	0·14	0·23	0·75	...	...	...

These results show that the effect of the original tempering is similar to that which would be obtained by tempering for 1 hr. between 300° and 350° C.   An increase in the limit of proportionality is effected by treatment at 400° C. for 1 hr.

This is also borne out by the determinations of the permanent set on direct loading at elevated temperatures shown in Table VIII. (p. 207).   Here, after retempering at 350° C., a definite improvement is seen at loads of 35 tons, and 50 tons at 300° C.

Experiments carried out on exactly the same lines as those described on p. 200, with the object of determining the permanent set on bending, gave the results shown in Table IX. :

TABLE IX.—*Oil-Hardened and Tempered Steel Wire.   Loss of Tension (expressed as Percentage of Calculated Initial Tension) on Heating to Various Temperatures after Original Treatment and after Retempering.*

		Chromium-Vanadium Steel.			Carbon Steel.					
		After Original Treatment.			Tempered at—					
					400° C.			500° C.		
Average Calculated Initial Tension. Tons per sq. in.		73.	53.	40.	79.	56.	33.	80.	58.	36.
Loss of tension at various temperatures	Atmos.	4	Nil	Nil	3	2	Nil	6	Nil	Nil
	100° C.	7	5	3	8	2	Nil	11	5	4
	150° C.	12	7	6	6 *	5	4	17	7	3
	200° C.	16	10	6	11	4	4	22	9	6
	250° C.	21	14	10	15	7	4	24	11	4
	300° C.	34	26	16	22 †	9 ‡	4	32	24	7
Loss of tension at 200° C. after tempering at—	350° C.	14	10	6	...	...	...	...	...	...
	400° C.	12	10	3	...	...	...	...	...	...
	500° C.	12	10	3	...	...	...	...	...	...

* Initial tension, 69 tons per sq. in. | These figures were not used in calculating
† Initial tension, 63 tons per sq. in. | the average.
‡ Initial tension, 43 tons per sq. in. |

The carbon steel was in the form of cold-drawn wire—wire *B* of *R.D. Report, No.* 60,[3] containing 0·75 per cent. of carbon and 0·70 per cent. of manganese, oil-hardened from 900° C. and tempered at 400° and 500° C. in the form of short lengths.

The mechanical properties are shown in Table VII., and determinations of loss of tension or permanent set on bending are given in Table IX.

PLATE XXXVIII.

Microstructure of cold-drawn chromium-vanadium steel wire.   Magnification 1000 diameters
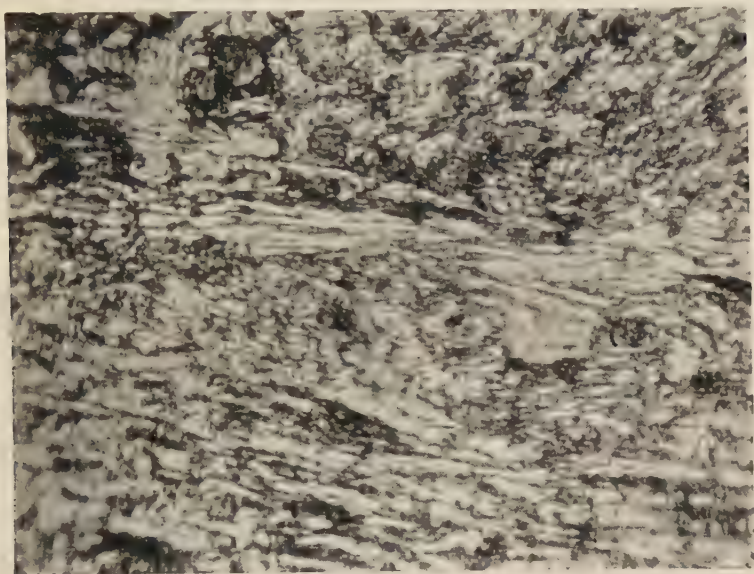
FIG. 3.—As drawn.

FIG. 4.—After heating for 1 hr. at 600°C.

PLATE XXXIX.

Microstructure of cold-drawn chromium-vanadium steel wire.   Magnification 1000 diameters.
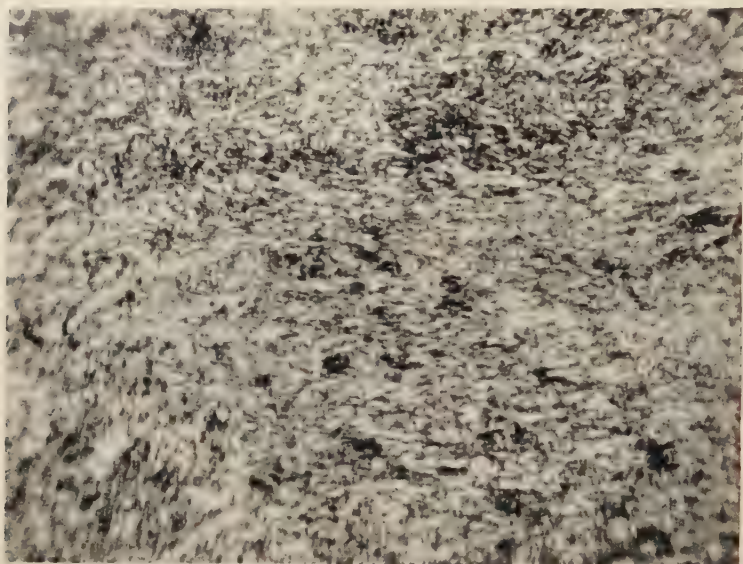
FIG. 5.—After heating for 1 hr. at 700°C.

FIG. 6.—After heating for 1 hr. at 750°C.

Under high stresses at raised temperatures, oil-hardened and tempered wire is decidedly inferior to cold-drawn and low-temperature heat-treated wire of the same composition. Further objections which may be raised to the use of hardened and tempered wire are the difficulty of treatment, and the risk of decarburisation and of lack of uniformity in properties.

CONCLUSIONS.

An examination of the properties of cold-drawn chromium-vanadium steel wire shows that conclusions previously arrived at in connection with carbon steel wire are applicable when suitable modifications of the quantitative data have been made.

Thus, complete restoration of elasticity at atmospheric temperature requires treatment at 300° C. instead of 200° C., and other changes which occur on low-temperature heat treatment are comparable in extent when the chromium-vanadium wire has been heated at a temperature about 100° C. higher than that applied to the carbon steel wire.

In its behaviour under stress at raised temperatures, the superiority of cold-drawn chromium-vanadium steel treated for 1 hr. at 400° C. over the most suitably treated cold-drawn carbon steel wire (1 hr. at 300° C.), and over the same steels hardened and tempered, is considerable, as shown in the following table :

Test. (Tension in the Wire, 50 tons per sq. in.)	Type of Wire and Treatment.			
	Carbon Steel.	Chromium-Vanadium Steel.	Carbon Steel.	Chromium-Vanadium Steel.
	O.-H. 900° C. T. 400° C.	O.-H. 900° C. T. 400° C.	Cold-Drawn, heated at 300° C.	Cold-Drawn, heated at 400° C.
	° C.	° C.	° C.	° C.
Bending : Temperature at which loss of tension amounts to 5 per cent. . . .	150	< 200	160	300
Direct loading : Temperature at which permanent set amounts to 0·03 per cent. . .	...	150	160	250

O.-H. = oil-hardened ; T. = tempered.

Note.—0·03 per cent. permanent set is equivalent to a loss of tension of 4 tons per sq. in.

1928—ii.

The author wishes to express his thanks to Mr. H. F. Hall, B.Sc., A.M.I.Mech.E., for carrying out the tests with the mirror extensometer, and to Dr. R. H. Greaves for his interest in the progress of the work.

REFERENCES.

(1) P. GOERENS : *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1911, vol. iii. p. 320.

    A. T. ADAM : *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1920, vol. x. p. 65.

    L. AITCHISON : *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1923, vol. xii. p. 113.

    J. A. VAN DEN BROEK : *Iron and Steel Institute : Carnegie Scholarship Memoirs*, 1918, vol. ix. p. 125.

    C. CHAPPELL : *Journal of the Iron and Steel Institute*, 1914, No. I. p. 460.

    S. H. REES : *Journal of the Iron and Steel Institute*, 1923, No. II. p. 273.

    S. C. SPALDING : *Transactions of the American Society for Steel Treating*, 1926, vol. ix. p. 685.

(2) *Watertown Arsenal Report*, 1917, p. 135.

(3) R. H. GREAVES : *Research Department, Woolwich, Report No.* 60.

(4) HOUDREMONT and E. BÜRKLIN : *Stahl und Eisen*, 1927, vol. xlvii. p. 90.

(5) H. MOORE and S. BECKINSALE : *Faraday Society, General Discussion on Failure of Metals*, 1921, p. 162 ; *Journal of the Institute of Metals*, 1922, No. 1, p 149.

VISITS AND EXCURSIONS AT THE SPANISH MEETING.

FOR the second time in the history of the Iron and Steel Institute, the Autumn Meeting was held at Bilbao in 1928. For the purpose of making the arrangements for the meeting, an influential Reception Committee was formed with the Excmo. Sr. Conde de Zubiría as President. The Honorary Presidents were :—Excmo. Sr. Presidente del Consejo de Ministros (Prime Minister and President of Council of Ministers) ; Excmo. Sr. Ministro de Fomento (Minister of Public Works) ; Excmo. Sr. Ministro de Trabajo (Minister of Labour) ; His Excellency the British Ambassador ; Excmo. Sr. Gobernador Civil (Civil Governor of the Province of Vizcaya) ; Excmo. Sr. Gobernador Militar (Military Governor of the Province of Vizcaya) ; Excmo. Sr. Presidente de la Diputación (President of the Provincial Government) ; and Excmo. Sr. Alcalde de Bilbao (Lord Mayor of Bilbao). Sir Ramón de la Sota, K.B.E., Excmo. Sr. Marqués de Arriluce de Ibarra, Excmo. Sr. D. Juan T. de Gandarias, Excmo. Sr. D. Federico de Echevarría, Excmo. Sr. Marqués de Triano, and Sir John Field Beale, K.B.E., were Vice-Presidents. The Committee was composed of the following noblemen and gentlemen :—Excmo. Sr. Marqués de Chávarri, Director of the S.A. Altos Hornos de Vizcaya ; Sr. D. Restituto de Goyoaga, Director of the S.A. Altos Hornos de Vizcaya ; Sr. D. Rafael de Zubiría, Director of the S.A. Altos Hornos de Vizcaya ; Excmo. Sr. Conde de Motrico, Director of the S.A. Altos Hornos de Vizcaya ; Iltmo. Sr. D. Eduardo Merello, General

Manager of the S.A. Altos Hornos de Vizcaya ; Iltmo. Sr. D. Alfonso de Churruca, Assistant Manager of the S.A. Altos Hornos de Vizcaya ; Excmo. Sr. D. José J. de Ampuero, Director of the Cia. Anón. Basconia ; Sr. D. Pedro de Gandarias, Director of the Cia. Anón. Basconia ; Sr. D. Jesús Chirapozu, Commercial Manager of the Cia. Anón. Basconia ; Sr. D. Leopoldo Goicoechea, Works Manager of the Cia. Anón. Basconia ; Excmo. Sr. D. Luis M. de Aznar, Vice-Chairman of the Cia. Siderúrgica del Mediterráneo ; Excmo. Sr. Conde de Aresti, Director of the Cia. Siderúrgica del Mediterráneo ; Sr. D. Eduardo de Aburto, Managing Director of the Cia. Siderúrgica del Mediterráneo ; Sr. D. Jerónimo Roure, Engineer of the Cia. Siderúrgica del Mediterráneo ; Sr. D. Enrique Ocharan, Director of the S.E. Babcock and Wilcox ; Excmo. Sr. Marqués de MacMahon, Director of the S.E. Babcock and Wilcox ; Sr. D. José L. Torróntegui, General Manager of the S.E. Babcock and Wilcox, President of the Asociación de Ingenieros Industriales ; Sr. D. Ramón de la Sota y Aburto, Managing Director of the Cia. Euskalduna ; Sr. D. Antonio Sierra, Secretary of the Cia. Euskalduna ; Iltmo. Sr. D. Alejandro Zaballa, General Manager of the Cia. Euskalduna ; Excmo. Sr. Marqués de Urquijo, Director of the S.E. de Construcción Naval ; Sr. D. José María Chávarri, Director of the S.E. de Construcción Naval ; Excmo. Sr. D. Nicolas Fúster, General Manager of the S.E. de Construcción Naval ; Sr. D. Alejandro Calonge, Assistant Manager of the S.E. de Construcción Naval ; Sr. D. José Botín, Works Manager of the S.E. de Construcción Naval ; Sr. D. Luis de Echevarría, Managing Director of the S.A. Echevarría ; Sr. D. Joaquín Adán, Commercial Manager of the S.A. Echevarría ; Sr. D. Fernando Jaúregui, Proprietor of the Fábrica de Astepe ; Sr. Marqués de Monte Rico, General Manager of Tubos Forjados ; Sr. D. Luis Beraza, General Manager of the Sociedad Santa Ana de Bolueta ; Sr. D. Gregorio Prados Urquijo, Manager of the Central Siderúrgica ; Sr. D. Emilio Coste, Inspector of the Central Siderúrgica ; Sr. D. Vicente Rojo de Cubillo, General Manager of the Talleres de Guernica ; Sr. D. Lázaro Ituarte, General Manager of Vda. é Hijos de I. Ituarte ; Sr. D. Manuel E. de Goyarrola, Manager of the S.A. San Pedro de Elgoibar ; Sr. D. Justino Lecuona, General Manager of the Talleres de Deusto ; Sr. D. Manuel Castellanos, General Manager of the Cia. Franco-Española de Alambres ; Sr. D. Luis Quechler,

General Manager of the Talleres de Zorroza ; Iltmo. Sr. D. Enrique Alonso, General Manager of the S.A. Aurrera ; Iltmo. Sr. D. Fortunato Leria, General Manager of the Talleres de Miravalles ; Sr. D. Ricardo S. Rochelt, Fabrica de Embase de Hojadelata ; Sr. D. Ismael Figaredo, Manager of the Fábricas de Moreda y Gijón ; Sr. D. Emilio Salomón, Engineer of the Fábricas de Moreda y Gijón ; Sr. D. Gaspar Viedma, Engineer of the Fábrica de Mieres, S.A. ; Sr. D. Aurelio Ayuela, Works Manager of the Fábrica de Mieres, S.A. ; Sr. D. Ramón Quijano, Managing Director of the S.A. José María Quijano ; Sr. D. Bartolome Darnis, General Manager of the Nueva Montaña, S.A. (Santander) ; Iltmo. Sr. D. Antonio Lucio Villegas, Manager of the S.M. Duro Felguera ; Sr. D. Jesús Canga, Engineer of the S.M. Duro Felguera ; Sr. D. José de Orueta, Aceros al Horno Electrico, Renteria ; Sr. D. Angel Garin, Manager of the Fundiciones de Vera S.A. (Vera, Navarra) ; Sr. D. Toribio Aguirre, General Manager of the Unión Cerrajera, S.A. (Mondragón) ; Sr. D. Antonio Monasterio, General Manager of the Cia. Auxiliar de Ferrocarriles (Beasain) ; Mr. W. Simons, Director of the Compañía Minera Orconera ; Mr. E. J. George, Director of the Compañía Minera Orconera ; Mr. Mark Fenwick, Director of the Compañía Minera Orconera ; Mr. Thomas E. Davies, General Manager of the Compañía Minera Orconera ; Sr. D. Horacio Echevarrieta ; Sr. D. Enrique Leyton, General Manager of the Ferrocarril de Galdames ; Sr. D. Santiago G. de Bellefond, General Manager of the Sociedad Minera Franco-Belga ; Sr. D. Enrique Guyot, Engineer of the Sociedad Minera Franco-Belga ; Sr. D. Luis Lezama Leguizamón ; Sr. D. Luis Núñez Arteche ; Sr. D. Luis Ocharan ; Sr. D. Manuel Taramona ; Sir Frederick L. Macleod ; Iltmo. Sr. D. Eduardo de Landeta, Director of the Mina Unión ; Sr. D. Julio Arteche, Director of the Cia. Minera de Dícido ; Sr. D. Daniel Zubimendi, General Manager of the Cia. Minera de Dícido ; Sr. D. José Luis de Aznar, Director of the Cia. Minera de Setares ; Sr. D. Joaquín Gamón, Engineer of the Cia. Minera de Setares ; Iltmo. Sr. D. Luis Barreiro, General Manager of the Cia. Minera Morro de Bilbao ; Sr. D. Venancio Echevarría, General Manager of the Banco de Vizcaya ; Sr. D. Enrique Zárate, Director of the Banco de Bilbao ; Sr. D. Fernando de Zubiría, Director of the Banco del Comercio ; Sr. D. José F. de Lequerica, Director of the Banco Urquijo Vascongado ; Mr. H. S.

Cartwright, General Manager of the Banco Anglo-Sud-Americano ; Mr. T. Ifor Rees, British Consul in Bilbao ; Mr. James Innes, British Vice-Consul in Bilbao ; Sr. D. Antonio Barandiarán, Town Councillor ; Sr. D. Luis Arana, Member of Provincial Government ; Sr. D. Enrique Borreguero, Inspector of Mines ; Sr. D. José Ucelay, Inspector of Public Works ; Sr. D. Manuel Prieto, Inspector of Industries ; Sr. D. Luis Camiña, Manager of the Bilbao Harbour Board ; Iltmo. Sr. D. Roberto López Barril, Commandante of the Port of Bilbao ; Iltmo. Sr. D. Jaime del Ojo, Chief Justice ; Iltmo. Sr. D. Federico Botella, Chief Excise and Customs Officer ; Iltmo. Sr. D. Valeriano Balzola, Chairman of the Chamber of Commerce ; Sr. D. Ramón María de Rotaeche, Chairman of the Chamber of Mine-Owners of Vizcaya ; Excmo. Sr. D. Federico de Echevarría, Chairman of the Federation of Manufacturers in Vizcaya ; Iltmo. Sr. D. Remigio de Eguren, Chairman of the Federation of Industries ; Sr. D. Máximo Abaunza, Head Master of the High School ; Iltmo. Sr. D. Ramón Berge, Managing Director of the National Federation of Industries ; and Sr. D. Julio de Lazúrtegui.

The Executive Committee consisted of :—Iltmo. Sr. D. Alfonso de Churruca, Chairman, Iltmo. Sr. D. Valeriano Balzola, Mr. Thomas E. Davies, Sr. D. Ramón Quijano, Sr. D. José L. de Torróntegui, Sr. D. Ramón M. de Rotaeche, Iltmo. Sr. D. Jerónimo Roure, with Iltmo. Sr. D. Luis Barreiro as Hon. Secretary.

The main party left London by a special train of the Southern Railway on Friday, September 21, reaching Paris about 5.30 P.M. They were accommodated for the night at the Hôtel Palais d'Orsay, continuing their journey early on the morning of the 22nd by the ordinary express to Irun, the Spanish frontier station, which was reached about 11 P.M. Here they were met and welcomed by Mr. Alfonso de Churruca and Mr. Luis Barreiro, respectively the President and Hon. Secretary of the Executive Committee. Through their kind influence exemption from the usual Customs examination was granted, and the whole party was able immediately to enter the special train provided to take them over the remaining few miles of their journey to San Sebastian, where a further welcome awaited them by Sir Ramón de la Sota, Mr. E. Coste, Mr. J. Roure, Mr. J. de Orueta and others. They proceeded at

once to their respective hotels, where accommodation had been reserved for them by the kind assistance of Mr. de Orueta.

On Sunday, September 23, the President and Members of Council with their ladies, together with some of the members representing countries other than the United Kingdom, were received by Their Majesties Queen Victoria and Queen Maria Cristina at the Royal Palace of Miramar. The party was introduced by the Marqués de Arriluce de Ibarra, Mr. de Churruca, and Mr. Barreiro. The President, in a short address, expressed, on behalf of the party, their sense of the extreme honour which Their Majesties were graciously pleased to accord to the members of the Institute in extending to them their Royal welcome on their arrival in Spain. Their Majesties acknowledged the President's address and shook hands with each member of the party.

On leaving the Royal Palace, the President and members all proceeded to the Palace of the Provincial Government of Guipuzcoa, where they were received by the President of the province, Mr. José A. Lizasoain, and the Alcalde and Municipal Council of San Sebastian. Mr. de Churruca again introduced the party, and in a brief speech referred to the antiquity of the metallurgical and other industries of the region, to which Mr. Talbot suitably replied. Refreshments were served, and the visitors were conducted through the rooms of the Provincial Government Palace, which contained a number of interesting portraits and pictures of historical interest. Among these may be specially mentioned a picture of the landing of El Cano, the first circumnavigator of the globe, on his return to Seville, together with relics of that voyage, and a portrait of San Ignacio de Loyola, the founder of the Society of Jesus. Both these men were natives of the province of Guipuzcoa.

After the reception the members were driven by motor around the Bay, and finally up to the height of Monte Igueldo, where lunch was served. The President of the province, the Alcalde of San Sebastian, Mr. J. de Orueta, the Marqués de Arriluce de Ibarra, Mr. A. de Churruca, Mr. and Mrs. Barreiro, Mr. E. Coste, and Mr. Antonio Monasterio were among the hosts. During lunch the visitors were entertained by a group of boys, who played primitive Basque airs on pipes. After lunch troupes of boys in white and red national dress performed Basque dances in the garden of the restaurant. For the afternoon complimentary tickets for

the bull-fight and for pelota games, according to choice, were distributed by the Committee.

In the evening all the members and ladies were entertained at dinner at the Grand Casino by invitation of the Provincial and Municipal Authorities and by the Metallurgical Industries of the Province of Guipuzcoa. Mr. J. de Orueta presided, and after welcoming the guests gave a short historical account of the development of the industries of Guipuzcoa from ancient times to the present day. The President, Mr. Talbot, replied in a few words, and then called on Professor Louis, who, addressing the assembly in Spanish, expressed the most cordial thanks of the visitors to their hosts for their charming hospitality. An exhibition of Spanish dancing and the playing of national songs and airs followed.

On Monday, September 24, the whole party left San Sebastian early by motor for Bilbao ; they travelled in two groups. The first group, consisting of about thirty people, went *viâ* Tolosa to Beasain, where they visited the works of the Cia. Auxiliar de Ferrocarriles. They were received on arrival by Mr. Antonio Monasterio, Director of the Company, and, accompanied by Mr. A. Garin and Mr. E. Coste, were shown over the works, which were founded in 1901. The works are equipped with every modern device for the manufacture of railway wagons and carriages, the total production of vehicles per year being about 6500. Besides this a large number of tyres and wheels mounted on axles are supplied to other factories. On the conclusion of their visit the guests were entertained with light refreshments, after which they resumed their journey, taking the road over the hills to Azcoitia.

The second group of members and all the ladies of the party travelled by motor char-à-banc from San Sebastian by the beautiful coast road, stopping at Zumaya to see the Zuloaga Museum containing a fine collection of paintings by " El Greco," and a number of objects of antiquarian interest. Here they were received by Mr. Zuloaga, the collector and owner of the Museum. They then travelled on to Azcoitia, joining the first party for lunch at the Hotel Isabel II. After lunch a visit was paid to the Monastery and Church of San Ignacio de Loyola, in the immediate neighbourhood. The party was welcomed by the rector, the

Rev. Cesares Ibero, and some of his colleagues. The journey was then continued by car to Eibar, where a halt was made to enable a visit to be paid to the famous factory of Eibar, renowned for the manufacture of armour, firearms, tools, and ornamental metal work. The workmen and engravers engaged in this industry succeed one another from generation to generation, and are highly skilled in the production of damascene work. From the factory the members proceeded to the " Escuela de Armeria," and after seeing the showrooms, containing an exhibition of the firm's artistic products, the visitors were entertained in the garden by choral music sung by a choir of boys which had specially come over from Motrico for the occasion. Tea was offered by the Town Council of Eibar, and the whole party then resumed their journey to Bilbao, reaching the Carlton Hotel in that city about 8 P.M.

The General Meeting opened at 10 A.M. on Tuesday, September 25, in the magnificent rooms of the Alfonso XIII. High School, which had generously been placed at disposal for the purpose. In the gallery leading to the Assembly Hall of the School a large collection of mineral specimens was arranged. These included typical ore specimens from the following mines : Abandonada, Silfide, El Morro, Somorrostro, Elvira, Orconera, Setares, Dícido, the mines of the Riff (Morocco), and Setolazar. A fine general plan of all the mines of Vizcaya was also displayed.

In the hall a large company of distinguished personalities was assembled on the platform. By special command the Government was represented by the Civil Governor of the province, Mr. César Ballarin ; the Director-General of Industry and Commerce, Mr. César Madariaga ; and the Assistant Director, Mr. Flores Posada. There were also present Mr. Valeriano Balzola, representing the Mayor ; Mr. Esteban Bilbao, President of the Diputación ; General Souza, Military Governor ; Count de Zubiría, President of the Reception Committee ; the Marqués de Arriluce de Ibarra ; the Marqués de Triano ; Mr. J. T. de Gandarias ; Mr. A. de Churruca, President of the Executive Committee ; Sir Ramón de la Sota ; Mr. T. E. Davies, General Manager of the Orconera Company ; Mr. Ramón Quijano ; Mr. J. L. de Torróntegui ; Mr. R. M. de Rotaeche ; Mr. J. Roure ; Mr. Luis Barreiro, Hon. Secretary of the meeting ; and many other prominent gentlemen.

The Civil Governor declared the session open, and Mr. V. Balzola, Chairman of the Chamber of Commerce, expressed the regrets of the Alcalde that he was unavoidably prevented, by other important engagements, from being present. Count de Zubiría then delivered an interesting address, which, together with a full account of the Proceedings, will be found elsewhere in this volume.

On the termination of the session in the Assembly Hall, special tramcars were lined up in the Gran Via to convey the members to the Town Hall, where the Alcalde was waiting to receive the guests at midday. Many private cars were also placed at the disposal of members. The large reception-room at the Town Hall was soon filled with the guests. Count de Zubiría introduced the President, Mr. Talbot, and the Council ; and the Alcalde, Mr. Ortiz de la Riva, extended a most cordial and friendly welcome to the city of Bilbao. Mr. Talbot replied thanking the Alcalde and the members of the Municipal Council for their most hospitable reception, and made reference to the marvellous progress and development of the city of Bilbao and the industries of the district since the last Spanish meeting of the Institute, thirty-two years ago. When these ceremonies were concluded, the members and their ladies passed to the Arab Salon, where an excellent light repast, with wines, was served. Afterwards the guests were shown by their hosts through the Council Chamber and rooms adjoining, containing many paintings and other artistic treasures which were much admired.

The party then proceeded to the Bilbaina Club, where they were to be entertained to luncheon by the Mining Companies of Vizcaya. One hundred and eighty-two guests were present, and as the dining-hall of the Club was not large enough for the accommodation of so many, additional tables had been laid in several adjoining rooms and loud-speakers had been installed to enable the speeches in the principal room to be heard. All the rooms were beautifully decorated, and various musical pieces were rendered by an orchestra. The principal table was presided over by Count de Zubiría, Mr. C. Madariaga, Mr. Talbot, the Marqués and Marquésa de Arriluce de Ibarra, the Civil Governor, the President of the Diputación, Sir Ramón de la Sota, General Souza, Sir John Field Beale (Chairman of the Orconera Company), Mr. A. de Churruca, Mr. J. T. de Gandarias, and others. Mr. J. T. de Gandarias welcomed the visitors in the name of the associated Mining

Companies of Vizcaya. Sir John Field Beale also spoke in the name of the Orconera Company, and other speeches followed from Mr. F. W. Harbord, Mr. C. Madariaga, and Count de Zubiría. Mr. Talbot took occasion to announce to the assembly that Count de Zubiría had that day been elected an Honorary Member of the Institute.

The proceedings terminated at 3.30 P.M., and the guests then embarked at Arenal on the steamers *Ayeta-Mendi* and *Arin-Mendi*, kindly placed at their disposal by Messrs. Sota and Aznar, and on petrol launches belonging to the Sociedad de Construcción Naval, to Mr. L. Aznar, to the Count de Zubiría, and to the Marqués de Arriluce.

They proceeded down-river as far as the harbour, which opens out on the Bay of Biscay, affording a beautiful panorama bordered with hills. The launches then turned about and came up to Sestao, where the whole party landed and visited the steelworks of the Altos Hornos Company. They were received by the Directors Count de Zubiría, Mr. A. de Churruca, the Marqués de Arriluce, Mr. Ibarrola, and Mr. Goyarrola. After inspecting the fine plant, which consists of three blast-furnaces, eight basic Siemens furnaces of 25 tons, cogging-mills, plate-mills, sheet-mills, and forges, they boarded the special train which conveyed them to Baracaldo. Here a visit was paid to the principal works of the Altos Hornos Company, with which the members were much impressed. They were shown the five batteries of coke-ovens, producing about 400 tons of coke per day, four blast-furnaces with a daily output of 220 tons, a mixer of 250 tons, with a new one of 600 tons under construction, two Bessemer converters, and three Siemens furnaces of the Maerz type of 60 tons capacity in course of construction. They also visited the blooming-mills and the new rail-mill, all the plant being in full operation. At the end of the inspection, the whole party assembled on the platform of the new open-hearth furnace department, where an ample tea and refreshments were served. After resting here for a time, they re-embarked on the launches and proceeded up the river, returning to the Carlton Hotel.

The next morning, Wednesday, September 26, was spent in visiting the principal iron mines in the neighbourhood of Bilbao. As it was not possible in the time available for members to visit

all the mines, the party was divided into three groups.   Group A travelled by train from Bilbao to Luchana, and thence by the narrow-gauge railway to the central station of the Orconera Mining Company. Sir John Field Beale, Chairman, Mr. W. Simons, and Mr. E. J. George, Directors, and Mr. T. E. Davies, General Manager of the Company, accompanied the visitors and showed them round the mine workings of Concha I., Concha II., and Gallarta.   At noon, in the Concha II. mine, warning signals were given preparatory to shot-firing, and from a good position on the hill above the mine the members were able to witness the effect of the successive explosions by which large masses of ore were detached from the sides of the open quarry, falling in loose heaps at the foot of the wall.   A visit of inspection was paid to the kilns, and after a most interesting morning the whole party returned by train to Bilbao.

Group B visited the mines of the Franco-Belga Company, and Group C those of Dícido and Setares, the journey to these places being performed by motor conveyance.   At each place they were met by the Directors and Managers, and escorted through the workings.   About 1 P.M. all the parties reunited at the Carlton Hotel, and, after lunch, continued the second session of the General Meeting at the Alfonso XIII. High School, at which the discussion of papers and the formal business of the meeting were concluded. A full report of these proceedings is recorded in this volume.

At 5 P.M. the whole assembly adjourned to the Palace of the Diputación (Provincial Government), where they were received by the President of the Diputación, Mr. E. Bilbao.   The Hall of Assembly was beautifully decorated for the occasion, and as soon as the guests had taken their seats, Mr. Bilbao, in an eloquent speech, expressed his pleasure at their visit, and his conviction that such an event could not fail to strengthen the friendly relations existing, both in the political and industrial domains, between Spain and Great Britain.   Mr. Talbot replied, giving utterance to the feelings of admiration and gratitude with which all the visitors were inspired by the warmth of their reception and the generous hospitality of their hosts in Bilbao.   Tea and refreshments followed, and the proceedings concluded about 6 P.M.

The whole party was then conducted to the Fronton Euskalduna, a covered court devoted mainly to pelota games.   Here a

number of first-class pelota players engaged in a match, and the visitors were greatly entertained by the marvellous display of skill and agility on the part of the rival teams.

The return to the hotel was made in time to allow the visitors a short interval of rest before leaving at 8 p.m. for Las Arenas, some ten miles distant, where they were invited to dine at the Maritimo Club as guests of the metallurgical works of the Bilbao district. They proceeded to Las Arenas by special tramcar, special train, and by private cars. A magnificent banquet was prepared, and Count de Zubiría presided over a brilliant assembly of guests. The party included those who had been present at luncheon on the preceding day, as well as other notable personalities. The Marqués de Arriluce spoke in welcome of the guests, and Mr. Talbot replied, complimenting the hosts on the highly advanced development of their works and industries. Dancing followed, and the festivities were kept up to a late hour.

Thursday morning, September 27, was devoted by members to visits to works in the immediate neighbourhood of Bilbao. The ladies of the party meanwhile started on an excursion to Gorliz on the coast, where they visited the children's seaside sanatorium at that beautiful spot. They were received by the ladies of the Board, the Sisters, and the Chief Medical Officer, who conducted them over the establishment. The spacious buildings and modern equipment, together with the magnificent situation, produced the greatest admiration, and indeed this Institution may be regarded as a model of its kind. On leaving this place, the ladies proceeded by road over Monte Sollube to Bermeo, and thence to Pedernales and Chacharramendi to join the members there.

On the same morning the members left the Carlton Hotel in groups, travelling by motor omnibus.

One group was conveyed to the works of the Babcock and Wilcox Company at Sestao, where they were received by the Directors and Managers, and were shown over the various departments for the manufacture of tubes, boilers, locomotives, cranes, and other machinery.

Another group visited the works of the Basconia Company at Dos Caminos, and were received by Mr. L. Goicoechea, the Technical Director, and Mr. Lequerica, and other members of the Board. They were conducted over the steelworks, visiting the

open-hearth furnaces, the foundries, the wire-rod mill, the sheet and tinplate mills, and they were able to witness the manufacture of tinplate in all its stages.

The works of the Sociedad Española de Construcción Naval at Sestao, with their shipyards, which stretch for nearly a mile along the river bank, and the departments for the construction of Diesel engines, steam turbines, and railroad material, were also thrown open for inspection.

Another party proceeded to the steelworks of Echevarría, manufacturers of special alloy steels and tool steels. The works are fitted out with every modern device for the production of such specialities. The wire-rod mills and the mill for rolling sections of special steels were also inspected, and a visit was paid to the well-equipped laboratory attached to the works.

The last group visited the Euskalduna Works at Olaveaga, where they inspected the graving docks and slipways for the building and repair of ships, and the shops for the construction of locomotives and wagons.

Members of the Reception Committee accompanied the parties to all these works, and the visitors were hospitably received everywhere by the Directors, Managers, and members of the technical staffs of the respective companies, who readily imparted to all inquirers information concerning their undertakings and operations. Descriptions of all the works and other enterprises in Vizcaya are contained in the excellent handbook specially prepared for the meeting, and printed in Spanish and English, by Mr. Emilio Coste, to whom everyone is greatly indebted for the useful information thus made available to them.

These visits being concluded, all parties re-entered their conveyances and travelled by road through the beautiful hilly country of Vizcaya to Chacharramendi, where they joined the ladies, who in the meantime had been visiting the sanatorium at Gorliz.

By 1.30 p.m. all had reunited at the summer resort on the Island of Chacharramendi, at which place they had been invited to take lunch by the Council of the province of Vizcaya and the Municipality of Bilbao. The entertainment again took the form of a magnificent banquet, with gaily decorated rooms, and the guests numbered about 300 in all. The President of the Diputación,

Mr. Esteban Bilbao, and Mr. Ortiz de la Riva, the Alcalde, presided, and the party included besides, the Director-General of Industry and Commerce, Mr. C. Madariaga, the Military Governor, General Souza, the Countess de Zubiría, the Marqués de Triano, Mr. J. T. de Gandarias, Mr. A. de Churruca, Mr. L. Barreiro, Mr. J. Roure, Mr. E. Coste, and other members of the Reception Committee.   The band of the Municipality of Guernica played a selection of Basque national airs, the audience showing their appreciation by their hearty applause.   At the end of the repast, Mr. E. Bilbao rose to express the satisfaction which it gave to the Provincial Council and to the Municipality of Bilbao to welcome Mr. Talbot and the members of the Iron and Steel Institute as their guests.   They had had the opportunity of visiting the factories and mines around Bilbao, and had thus been able to form an idea of the progress and vitality of the Spanish industries. They would shortly visit the historic Oak Tree of Guernica, emblem of the glorious past of the Basque race and its honourable history He proposed the health of the ladies, and in saluting them he presented to every one of them a leaf from that tree as a memento of the occasion.   A pressed leaf from the Oak of Guernica was then distributed to each guest present.   Mr. A. de Churruca, on behalf of the Executive Committee, also presented to each lady in the room a pretty and elegant gold pin with the Spanish national flag in coloured enamel thereon.   Mr. Talbot replied to Mr. Bilbao, thanking him and the Alcalde for their abundant hospitality. The party then broke up and drove on to Guernica, where there was just time to visit the Parliament House and the Oak of Guernica.   The band, which had accompanied them, played the Royal March, the British National Anthem, and finally the Guernikako Arbola.   The travellers then directed their journey to the mansion of Count de Zubiría at Ibarrecolanda.

The Count and Countess de Zubiría, respectively President of the Reception Committee and President of the Ladies' Committee, had issued invitations for the evening of Thursday, September 27, to attend a Garden Party at their country mansion.   The most elaborate and complete preparations had been made for the reception and entertainment of the guests.   Architects and landscape gardeners had transformed the grounds into an Oriental garden, all the details having been carried out in the most exquisite taste.

On a spot commanding a view, a large marquee had been erected in case of rain. Banks of flowers were arranged, and gigantic baskets filled with garlands hung suspended from the roof, with lights disposed among them and hanging from them. At one end two platforms were erected for the orchestra, and an excellent dancing floor had been laid down. Nearby a stage was placed for the celebration of a Basque Festival, including the representation of a wedding. After dark the whole of the grounds were illuminated by innumerable Venetian lamps, and corners of the grounds had been designed to represent a romantic garden, with artificial moon and stars, and here and there were placed tables for refreshments. Supper was served from the house, the Count and Countess de Zubiría and their sons acting as hosts and attending personally to their guests. The principal features of the evening were the Basque dances, the Aurresku and Antzesko, the one being led by Mr. A. de Orueta and the other by Mr. José de Mendizabal. The performance concluded with a representation of a Basque village fair. When it was ended, dancing began in the large marquee, the Marqués de MacMahon leading off with his daughter, Madame de Sota y Aburto. The brilliant and animated scene continued until late in the evening.

Thus concluded the three days' meeting at Bilbao of 1928, from which everyone who was privileged to be present carried away recollections of a thoroughly delightful and successful entertainment.

On Friday, September 28, several members of the party started on their homeward journey, but the majority remained to take part in the long-distance excursions.

An early start was made for Burgos by a party of about 65 of the visitors, accompanied by several members of the Reception Committee. On arrival at Burgos the travellers were conveyed to the Hotel Paris, where lunch was served, and then some hours were spent in visiting the great cathedral, the monastery of Miraflores, and the monastery of Las Huelgas. The journey was then continued by train to Madrid, which was reached late at night, and the whole party was accommodated in the Palace Hotel.

Saturday, September 29, was spent in sightseeing in Madrid, the Prado Museum being one of the chief attractions. In the afternoon all were invited to a Reception at the City Hall, where

they were received by the Alcalde and Municipal Council of Madrid. Mr. Talbot, the President, made reference to the disastrous fire at the Teatro de Novedades which had occurred a few days before, and in which many lives were lost.   He handed to the Alcalde a donation of 2000 pesetas, as a contribution from the members of the Institute to the fund organised by the Government for the relief of the sufferers.   The Alcalde acknowledged the gift with gratitude, and bade the members and their ladies a cordial welcome to the city of Madrid, which Mr. Talbot suitably acknowledged. The party then adjourned to a neighbouring room, where they were entertained by a magnificent orchestral concert, refreshments being served in the interval.

The whole of the following day, Sunday, was devoted to a visit to the Royal Palace of the Escorial, some thirty-five miles distant from Madrid, where the party was shown over the magnificent private apartments, the chapels, and the mausoleum of the kings of Spain.   In the evening of the same day a party left by the night train for Sagunto to visit the works of the Cia. Siderúrgica del Mediterráneo, a reference to which is given below.

The next day the members visited various places of interest in Madrid.   His Majesty King Alfonso had graciously granted permission for the party to visit the Royal Palace, and the Royal Armoury and the School of Mines were also inspected.   In the afternoon the members paid a visit to the Instituto Catolico de Artes e Industrias, where they were received by the rector, the Rev. Father F. G. Polavieja, the Principal, the Rev. Father J. A. Perez del Pulgar, and members of the staff.   After making a tour round the workshops, laboratories, and class-rooms, the members were entertained to refreshments before returning to their hotel. At both the School of Mines and the Instituto Catolico the visitors were much impressed with the completeness of the apparatus and equipment installed for the training of the students in the science and practice of mining and metallurgy.

On Tuesday, October 2, a whole day's excursion was made to Toledo.   Five or six hours were spent in seeing as many as possible of the wonderful monuments, ancient buildings, and Moorish houses.   At midday the members assembled for lunch at the Hotel Castilla, in the centre of the city.   They returned to Madrid in time to catch the night train to Cordoba, which was

1928—ii.   Q

reached early on the following morning (October 3). Immediately after breakfast at the Regina Hotel a visit was paid to the works of the Sociedad Española de Construcciónes Electro-Mecanicas, where the party was received by the Managing Director, Mr. Gonzague Palle, and the General Manager, Mr. Cantais. This company was founded in 1917 for the production of electrolytic copper, for brass founding, and for the manufacture of other copper alloys. These alloys, as well as aluminium, are rolled into plates, hoops, rods, discs, wire, and tubes. The company manufactures electric conductors of copper and aluminium. The capacity of the works is 12,000 tons of electrolytic copper per year, and the throughput of the melting furnaces is 150 tons of copper daily. A special feature is wire-drawing and copper wire-rope manufacture. The by-products recovered from the electrolytic process are gold, silver, and sulphate of copper.

The next visit was paid to the wine cellars of Messrs. Carbonell y Cia. Here the party was received by Mr. Carbonell and other members of his firm, famous for the wines of Montilla, which are produced from vines grown in the Sierra de Montilla and are held in high estimation. The principal brands are Montilla, Solera fina, Moriles fino, Solera Olorosa, and Flor de Montilla. Counters were laid out and the members were cordially invited to sample the various wines, which they proceeded to do with great goodwill. The party was also shown over the olive-oil works, where oil refining, bottling, and canning were in progress, the most up-to-date apparatus being employed for these purposes. The firm has the largest trade in the export of oil in Spain.

At 1.30 P.M. lunch was served at the Hotel Regina by kind invitation of the Compañia Electro-Mecanica, and this was followed by a visit to the celebrated Mosque of Cordoba, which, on the expulsion of the Moors from Spain, became the cathedral of the city. An excursion had been planned for the afternoon to Las Ermitas, but this, unfortunately, had to be abandoned owing to the breaking of a sudden storm of rain. In its place, however, a visit was arranged to the charming residence of Mr. Barreiro (a relative of Mr. Luis Barreiro of Bilbao), the house being a typical modern Spanish mansion, situated on the

range of hills overlooking the City of Cordoba.   In connection with this excursion and other local arrangements, the kind and hospitable services of Mr. Benito de Ybargüen Corbacho, mining engineer, were very much appreciated.   In the evening the journey was continued by train to Seville, which was reached about 9.30 P.M., the party being accommodated in the Hotel Angleterre.

On the morning of Thursday, October 4, visits were paid to the cathedral at Seville, including the Giralda, the Sacristy, the Chapter House and Treasury, and the tomb of Christopher Columbus.   On leaving the precincts of the cathedral, the party proceeded to the Alcazar, where they were conducted through the beautiful Patios and Gardens.   In the afternoon an excursion on the river Guadalquivir was made by kind invitation of the Port Authorities.   The party was received on board by Mr. José María de Ybarra, President of the Board of Harbour Works, Mr. J. Coll, and Mr. J. Delgado Brackenbury, Technical Director of the Harbour Works.   The new works were inspected and a very enjoyable journey for some miles down the river was made.

On Friday, October 5, a visit was paid to the Fabricas de Ceramica Artistica of Mensaque Rodriguez y Cia., where ornamental pottery work on a large scale is manufactured.

In the afternoon a visit was paid to the Spanish-American Exhibition (under construction at the time).   The whole party was received by the Alcalde-Presidente of Seville, the Directors of the Organising Committee of the Exhibition, and Mr. Francisco S.-Apellaniz, Mining Engineer and General Secretary of the Exhibition.   This gentleman explained the plan of the Exhibition and its construction, and gave some interesting information concerning the materials employed.   The visitors were afterwards entertained at tea in the Royal Pavilion.   A walk was then made through the gardens of the Exhibition, which is beautifully laid out in the María Luisa Park.

Late in the evening the members took the night train back to Madrid, and the next day proceeded to the frontier, making their way home *viâ* Paris and Boulogne.

VISIT TO THE WORKS OF THE COMPAÑIA SIDERÚRGICA DEL MEDITERRÁNEO.

A party of some sixteen members, accompanied by Mr. de la Sota, Mr. de Churruca, Mr. Roure, and Mr. Barreiro, left Madrid on Sunday, September 30, by the night train for Valencia, with the object of visiting the new plant of the Cia. Siderúrgica del Mediterráneo at Sagunto. At Valencia the party was met by Directors of the Company, and a special train awaited them which conveyed them for the remaining twelve miles to Sagunto. They proceeded immediately to visit the works, which are laid out on the most modern plan on a level strip of land close to the seashore. These works and the modern town of Sagunto lie at the foot of the high and steep ridge of rock on which still stand, in excellent preservation, the ruins of the old Roman fortress of Saguntum. The works comprise a modern battery of 70 coke-ovens with by-product recovery ; 48 per cent. of the gas is used to heat the battery, 10 per cent. for steam raising, and the rest for the generation of power and for the sintering plant. This latter plant consists of two units on the Dwight-Lloyd system, each of which is capable of producing 185 tons of agglomerates in 24 hr. There are two blast-furnaces, each with a daily capacity of 400 tons of pig iron, or 450 if pressed. The ore is brought from the Sierra Menera in the neighbourhood. Skip charging is employed, and a 600-ton mixer is attached to the blast-furnaces.

There are four Siemens steel furnaces of 85 to 90 tons capacity, served by Wellman chargers and fired by producer-gas. The charge is 85 per cent. of liquid pig iron and 15 per cent. of scrap, the output being $2 \cdot 8$ heats per day. The rolling-mills are all electrically driven, and consist of a blooming-mill, a three-high rail-mill, a plate-mill, and a semi-continuous mill for merchant bar. Sixteen Babcock and Wilcox boilers are installed, all fired with blast-furnace gas and coke-oven gas. The steam pressure is 250 lb., and the boilers drive three sets of turbo-blowers and three sets of turbo-alternators, each of 3500 kw.

The visitors were conducted round the works by Mr. E. de Aburto and Mr. Ramón de la Sota, in company with Mr. Sanchez Arboleda and Mr. Aranzadi. Madame de la Sota also did the members the

honour of accompanying them for the greater part of the tour through the works.

On completion of the inspection of the works the whole party was entertained at the Managing Director's house to a magnificent lunch, presided over by the three ladies and the Directors of the Company.

Mr. de la Sota welcomed the guests in a graceful speech, and, after acknowledging the many courtesies and attentions received at the hands of the hosts, the party returned in the afternoon to Valencia, where they visited the old Silk Exchange and other places of interest. They finally took the night train back to Madrid, arriving on Tuesday morning, October 2, in time to join the excursion to Toledo.

OBITUARY.

WALDEMAR DYRSSEN died as the result of a motor-car accident on August 4, 1928. He was born in Stockholm in 1886, and graduated from the Royal Technical University in that city as a metallurgical engineer in 1908. For the following year he was employed in the department of construction of Les Petits-Fils de François de Wendel et Cie, Alsace-Lorraine. For the next three years he was blast-furnace and open-hearth superintendent with the Uddeholm Co., Sweden. From 1913 to 1915 he was a designing engineer in the department of construction of the Bethlehem Steel Co. He was next employed by the United States Steel Corporation as a metallurgical engineer, until in 1924 he joined the Blaw-Knox Co. as chief engineer of the furnace equipment department. While with the Steel Corporation he took part in the development of the Héroult electric furnace. He became a member of the Iron and Steel Institute in 1924, in which year he presented to that body a paper on " The Recovery of Waste Heat in Open-Hearth Practice."

MYLES KENNEDY, J.P., D.L., died suddenly on August 9, 1928, at the age of sixty-six. The descendant of a family intimately identified with the iron-ore mining and iron and steel industries of the Furness district, he was born on June 3, 1862 ; he was educated at Harrogate and the Royal School of Mines. He was the head of the firm of Kennedy Bros., and also held many important offices in connection with the directorship of public companies. During the war his expert advice on matters relating to the iron and steel industry and the production of munitions was freely sought and given. He was made a county magistrate in 1899 ; he was appointed deputy-lieutenant of the county of Cumberland in 1921, and during 1922–23 he filled the office of High Sheriff. He was elected a member of the Iron and Steel Institute in 1888.

ANDREW LAMBERTON died on August 23, 1928. He was the designer of several important steel plants in Scotland and England, and at his works at Sunnyside, Coatbridge, he built much of the machinery in operation in steelworks to-day. He became a member of the Iron and Steel Institute in 1894 ; in 1905 he was made a Member of Council, in 1914 he became a Vice-President, and in 1926 he was elected an Hon. Vice-President. He was awarded the Bessemer Gold Medal of the Institute in 1917 in recognition of his distinguished services in the development of mechanical engineering as applied to the manufacture of iron and steel.

Colonel DAVID LEWIS, V.D., J.P., an ex-High Sheriff of Glamorgan, died on May 30, 1928, at Fernhill, near Swansea, at the age of eighty.

With his brother (Mr. Rufus Lewis), who survives him, he was the freeholder of most of Gorseinon, the creation of his father, the late Mr. Thomas Lewis, and proprietor until recently of the Old Works, Gorseinon, the Bryngwyn steelworks, and the Cambria tinplate works, all of which works have now been taken over by the Grovesend group. He was also interested in the Mardy Works, and was a director of Dulais Tinplate Co., Pontardulais, the Swansea Gas Light Co., and Weaver & Co., millers. With his brother and sister he was a prominent figure in philanthropic work ; they built the parish church at Gorseinon as a memorial. He joined the Iron and Steel Institute in 1893.

ÉMILE MAYRISCH was killed in a motor-car accident on March 5, 1928, at the age of sixty-five. Born in 1862, he was educated at the University of Aix-la-Chapelle. In 1885 he commenced work as an apprentice with the Société des Hauts Fourneaux et Forges de Dudelange, and in the following year he was appointed to a position as chemist. Two years later he became works manager of the Société Anonyme de Hauts Fourneaux de Rodange, but after remaining for two years he returned to the former company as metallurgical engineer. In 1893 he became general secretary at Dudelange, and in 1897 he joined the board of directors. He held this directorship for fifteen years, until in 1911, when the three companies at Burbach, Eich, and Dudelange were amalgamated, which fusion was largely due to him, he was nominated technical managing director of the world-famous " Arbed." In 1918 he became sole managing director, and in 1920 he took up the office of chairman of the board of directors.

In the subsequent development of " Arbed " Mr. Mayrisch played a leading rôle, and through his efforts a variety of working agreements and alliances were entered into, such as that with the Eschweiler Bergwerks-verein, the formation of the Ciments Luxembourgeois, the absorption of Burgbrohl, the alliance with Schneider's, out of which arose the Société Métallurgique des Terres Rouges and the Société Minière des Terres Rouges. Columeta was created for the purpose of exporting products of Luxemburg to the four corners of the world. Later " Arbed " took over a predominant interest in the firm of Felten and Guillaume, founded the Belgo-Mineira in Brazil, participated largely in the Talleres Metalurgicos in the Argentine, entered into a contract with the Clouterie des Flandres, &c., to mention only a few of the company's commercial activities. All these were the work of Mr. Mayrisch ; it was he, with his clear foresight, who supplied the motive power for the movement towards rationalisation in the metallurgical industry of Europe. In 1922 he became a member of the Council of the Union Économique Belgo-Luxembourgeoise, in 1923 he was elected vice-president of the re-organised Red Cross Society of Luxemburg, while in 1926 he became chairman of directors of Arbed-Terres Rouges, president of the Comité Franco-allemand d'Information et de Documentation, and president of the Entente Internationale de l'Acier.

With all his many commercial and technical preoccupations, Mr.

Mayrisch was still able to find time to devote to works of philanthropy, and he took a deep interest in the care and welfare of his workpeople. He was elected a member of the Iron and Steel Institute in 1921.

WILLIAM C. MOUNTAIN died in his sixty-seventh year at Newcastle on January 26, 1928, after an illness lasting for about three years. At the age of fourteen he entered his father's business, Messrs. May and Mountain, of Birmingham, and served his apprenticeship in the various departments. Eight years later he joined the Gulcher Electric Light and Power Co., Ltd., as engineer and works manager, becoming later the managing director. In 1888 he joined Mr. Ernest Scott, of the Close Works, Newcastle ; two years later the firm was converted into a limited liability company with Mr. Mountain as managing director. In 1902 he was selected by the coalowners' association of Northumberland and Durham as one of their representatives on the advisory committee in connection with the Home Office inquiry into the application of electricity in mines, and was shortly afterwards appointed electrical expert to the Mining Association of Great Britain. He was a member of the Institution of Mining Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, and the North-East Coast Institution of Engineers and Shipbuilders. Since 1919 he had been a magistrate for the city of Newcastle. He joined the Iron and Steel Institute in 1915.

Dr. EMIL SCHRÖDTER died on October 31, 1928, in his seventy-fourth year. Born in Düsseldorf on February 26, 1855, he received his earlier education at the Realschule in that town, after which he went through courses of study at the Karlsruhe Polytechnicum and the Berlin Commercial Academy (Gewerbeakademie). He then performed his military service as a one-year volunteer in the Thirty-ninth Regiment of Fusiliers at Düsseldorf.

His first post as a young engineer was with the engineering firm of Ernst Schiess of Düsseldorf-Oberbilk ; thence he went to the Huldschinsky Works in Upper Silesia, where he first became connected with the iron and steel industry. In 1880 his activities were arrested by a severe attack of articular rheumatism, from the effects of which he suffered for a long time.

On November 1, 1881, he joined the staff of the Verein deutscher Eisenhüttenleute ; it was in this sphere of activity that he found his life's work. In 1885 he took over the direction of the Verein from F. Osann, together with the editorship of the Verein's journal, *Stahl und Eisen* ; from a monthly publication he worked it up first into a fortnightly and finally into a weekly periodical, and advanced it to the front rank of the most important technical papers. A glance through its pages will show that he was a prolific contributor, without counting his innumerable unsigned articles. The growth and development of the Verein may well be attributed entirely to Dr. Schrödter. At the celebrations of his seventieth birthday Dr. Vögler

said: "The Verein deutscher Eisenhüttenleute is the work of Emil Schrödter! That must not be forgotten. He created the Verein; he laid the foundation stone on which later generations could build and have built." Dr. Schrödter retired from the position of director of the Verein at the end of 1916.

His labours, however, were not limited to the control of the Verein and its journal. He was contemporaneous with the great growth of the German iron and steel industry, and he played a great part in the formation of syndicates and combines which strengthened the internal fabric of the industry and enabled it to compete successfully in the world's markets; among these was the Verein deutscher Maschinenbau-Anstalten, formed in 1891, and Dr. Schrödter took over the simultaneous direction of this body, for he was of opinion that the steel and machine industries " should advance hand in hand."

From its inception in 1901 until 1918 he was also in charge of the Testing Department of the Verein deutscher Eisenportlandzement-Werke, for he foresaw that the manufacture of cement from blast-furnace slag would be of great importance to the blast-furnace works of his country.

Dr. Schrödter was intimately connected with the Düsseldorf Exhibition held in 1902; it was through his agency that the Iron and Steel Institute was able to hold its Autumn Meeting of that year amidst such pleasant and interesting surroundings. He undertook the office of Local Hon. Secretary of the meeting, and its success was due in great measure to his skilful organisation and untiring activities on behalf of the members.

Dr. Schrödter was the recipient of many honours. In 1903 the Aachen Technical Institution conferred on him the honorary degree of Doctor of Engineering, and in 1906 the Verein deutscher Eisenhüttenleute presented him with the Carl Lueg Medal. He was elected an Honorary Member of the American Institute of Mining Engineers in 1909, of the Verein deutscher Maschinenbau-Anstalten in 1911, of the Iron and Steel Institute in 1912, and of the Verein deutscher Eisenhüttenleute in 1917. Orders were also conferred upon him by the German Government.

Dr. Schrödter always took a very keen interest in the affairs of foreign societies, and his regard was particularly marked for the Iron and Steel Institute; it is largely due to him that such cordial relations exist between this Institute and the Verein deutscher Eisenhüttenleute, which are still fostered by the present Secretary of the Verein, Dr. Petersen.

DANIEL WILLIAMS died in May 1928, at the age of seventy-three. He was a director of Llanelly Steel Co., Ltd., Old Castle Tinplate Co., Ltd., The Welsh Tinplate and Metal Stamping Co., Ltd., Ashburnham Tinplate Co., Kidwelly Tinplate Co., Pemberton Tinplate Co., and the Wellfield Galvanising Co., Ltd. He was at one time Mayor of Llanelly. He joined the Iron and Steel Institute in 1894.

(235)

SECTION II.

NOTES ON THE
PROGRESS OF THE HOME AND FOREIGN
IRON AND STEEL INDUSTRIES.

CONTENTS.

The Editor has been assisted in the preparation of these Notes by
R. ELSDON, Librarian of the Institute.

MINERAL RESOURCES.

BRITISH EMPIRE.

The Lignites and Brown Coals of the British Empire and the Uses to which they may be Put. Sir R. Redmayne. (Bulletin of the Imperial Institute, 1928, Vol. 26, pp. 154–161).

Conditions affecting the Petroleum Prospects of the Empire. Sir T. H. Holland. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 3, pp. 1–14).

Economics of the Petroleum Situation in British Dominions. Sir F. Black. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 3, pp. 15–39).

Progress and Prospects of Oil Production. E. H. Cunningham-Craig. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 3, pp. 40–61).

The Occurrence of Millerite and Associated Minerals in the Coal Measures of South Wales. F. J. North and W. E. Howarth. (Proceedings of the South Wales Institute of Engineers, 1928, Vol. 44, pp. 325–348).

The Coal Measures of the Gwendraeth Valley and Adjoining Areas. Emily Dix. (Proceedings of the South Wales Institute of Engineers, 1928, Vol. 44, pp. 423–510). The area dealt with in the paper is the western portion of the North crop of the South Wales coalfield, extending from Ammanford westwards through Cross Hands into the Gwendraeth Valley. The measures described constitute the Lower Coal Series.

The Oil Well and Later Developments at Hardstoft, Derbyshire. A. Wade. (Journal of the Institution of Petroleum Technologists, 1928, Vol. 14, pp. 357–387).

Analysis of Solid Fuels. J. H. H. Nicolls. (Canada, Department of Mines, Mines Branch, Investigations of Fuels and Fuel Testing, 1926, pp. 61–85). The compositions of a number of solid fuels occurring in Canada are tabulated.

Silica in Canada. L. H. Cole. (Canada, Department of Mines, Mines Branch, 1928, Report No. 686). This Report describes the occurrence and exploitation of silica in the territory from Fort William, Ontario, to the Pacific Coast of British Columbia. A chapter dealing with recent developments in the silica industry of Eastern Canada is appended.

Petroleum and Natural Gas in the Dominion of Canada. R. B. Harkness, G. S. Hume, O. B. Hopkins, S. C. Ells, R. T. Elworthy, and S. J. Cook. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 3, pp. 79-198).

Developments of Petroleum and Natural Gas in Canada. G. S. Hume. (Journal of the Institution of Petroleum Technologists, 1928, Vol. 14, pp. 669–676).

Canada and its Mineral Resources. W. van Leckwyck. (Revue Universelle des Mines, 1928, Vol. 18, June 1, pp. 208–225).

The St. George's Coalfield, Newfoundland. H. A. Baker. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 1, pp. 721–740).

Wabana Iron Mines and Deposits, Newfoundland. A. O. Hayes. (Mining and Metallurgy, 1928, Vol. 9, Aug., pp. 361–367).

British West Indies. A. P. Catherall. (Journal of the Institution of Petroleum Technologists, 1928, Vol. 14, pp. 676–679). A short discussion of the developments in the oil industry of British West Indies.

EUROPE.

Conditions in the Siegerland before, during, and after the State Subsidy. H. Willing. (Stahl und Eisen, 1928, Vol. 48, May 10, pp. 609–615). A review of the geological conditions of the Siegerland ore deposits shows with what difficulties the mines are faced, and indicates that great developments, rationalisation, and mechanisation in the small mines are almost impossible. The circumstances which would have brought the Siegerland mining industry to a standstill had the State not given assistance, and the good effect of that help on the output are described. As the subsidy came to an end in September 1927, costs must be reduced, and the directions in which reductions may be sought are pointed out.

Geology, Mineralogy, and Economic Geography of the German Moulding Sand Deposits. J. Behr. (Die Giesserei, 1928, Vol. 15, Sept. 21, pp. 945–948).

Historical Studies of the Mines and Works of the Saar District under the French Revolution and the First Empire (1792–1815). P. S-C. Deville. (Annales des Mines, 1928, Vol. 13, pp. 416–450).

The Coal Basin of Brive (Corrèze). V. Charrin. (Génie Civil, 1928, Vol. 93, Oct. 27, pp. 403–405). The geology of the district is described.

The Iron Ore Deposits in the Lölling-Hüttenberg-Friesach Range in Carinthia. H. Haberfelner. (Berg- und Hüttenmännisches Jahrbuch, 1928, Vol. 76, Oct. 1, pp. 87–114). The history of the iron industry and the geology of the district are discussed. Mining for iron was carried out in Carinthia in pre-Christian times ; after the subjugation of Noricum by Drusus (16 B.C.) Carinthia became a Roman province, and the famous Noric iron was obtained thence by the Romans.

The Swedish State and the Large Mining Companies (Contract of 1927). P. Nicou. (Annales des Mines, 1928, Vol. 14, pp. 5–70, 81–158, 177–238). The author discusses the agreements made between the State and the mining companies prior to 1927, and records the results of prospecting work in the deposits at Kirunavaara and Gellivara (1913–1923) ; he recounts the exploitation of the mines at those places and also at Grängesberg and Luossavaara up to 1926, and then discusses in detail the new contract of 1927. In appendices he gives the text of the 1927 contract, the directions to be followed in exploiting the mines at Kiruna, Luossavaara, and Malmberget, and for the amortisation of the properties belonging to the Luossavaara-Kirunavaara Co., a history of the Grängesberg-Oxelösund Co. up to the end of 1926, notes on the last working year of the Luossavaara-Kirunavaara Co. under the old régime, and the last balance-sheet of the Grängesberg-Oxelösund Co. on December 31, 1927.

Study of the Coal Basin of Belmez. A. Bourbon. (Revue de l'Industrie Minérale, 1928, No. 180, June 15, pp. 245–252). The geology of the Belmez coal basin near Cordoba, Spain, is discussed.

The Development of Mining in Jugoslavia. (Montanistische Rundschau, 1928, Vol. 20, Feb. 1, pp. 63–71). The article is based on a paper by W. Okaniewski in Zeitschrift des oberschlesischen Berg- und Hüttenmännischen Vereines, Vol. 66, Nos. 9 and 10. Ore and coal deposits are described and mining statistics are given.

AMERICA.

Tabulated Analyses of Representative Crude Petroleums of the United States. N. A. C. Smith and E. C. Lane. (United States Bureau of Mines, 1928, Bulletin 291). The report contains analyses of over 300 typical crude oils produced in the United States.

Geology and Oil and Gas Prospects of North-Eastern Colorado. K. F. Mather, J. Gilluly, and R. G. Lusk. (United States Geological Survey, 1928, Bulletin 796B).

Geology and Lignite Resources of the Marmarth Field, South-Western North Dakota. C. J. Hares. (United States Geological Survey, 1928, Bulletin 775).

Production and Development Problems in the Powell Oil Field, Navarro County, Texas. H. B. Hill and C. E. Sutton. (United States Bureau of Mines, 1928, Bulletin 284).

ASIA.

The Question of the Occurrence of Iron in Turkey. E. Nowack. (Zeitschrift für Praktische Geologie, 1928, Vol. 36, July, pp. 108–110). Various deposits of iron ore in Turkey and Asia Minor are reviewed ; they are all said to be too small to supply the raw material for a modern iron industry, though some of them were worked in olden times.

Geology of the Ta Ching Shan Range and its Coal Fields. C. C. Wang. (Bulletin of the Geological Survey of China, 1928, No. 10, Jan., pp. 1–18).

ORES—MINING AND TREATMENT.

Results Obtained by the Magnetic Prospecting at the Kamaishi Iron Mine. Y. Fujita. (Memoirs of the College of Engineering, Kyoto Imperial University, 1927, Vol. 5, Dec., pp. 133–151).

Iron Ore Mining in Vizcaya. J. Balzola. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 15).

Method of Mining at Wabana. J. B. Gilliatt. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 2, pp. 729–738).

Mechanical Engineering in Iron Ore Industry. A. Tanzig. (Mechanical Engineering, 1928, Vol. 50, Sept., pp. 675–682). The modernisation of mines on the iron range of Minnesota and their almost complete mechanisation are described.

Improvements in Methods of Preparation. K. Glinz. (Glückauf, 1928, Vol. 64, July 14, pp. 941–953). The author discusses the latest improvements in machines for the preparation and beneficiation of ores, &c. Some of the machines described are used for preparing coal for use as a pulverised fuel, while others are used to prepare ores for their beneficiation by the flotation or other processes.

The Economy of Roasting Spathic Ore. L. A. Richter. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 725–727). The costs of roasting spathic ore in the old types of kiln and in the new types known as the San Fernando and the Apold-Fleissner kilns are compared. The heat consumption in the double cone kiln of the Siegerland is 438,860 kg. cal. per ton of raw ore, in the Apold-Fleissner kiln 92,890 kg. cal., and in the San Fernando kiln it is 161,860 kg. cal. The old Donawitz kiln is slightly more economical than the Siegerland kiln. In addition to the heat economy of the two new types there is a considerable saving in wages, the wages in shillings per ton of crude ore treated being, for the Siegerland kiln 0·40 and for the Donawitz 0·20, while for the Apold-Fleissner they are 0·07, and for the San Fernando 0·20 shilling in each case. The comparative costs per ton of roasted ore are, for the Siegerland 4·08, Donawitz 3·10, Apold-Fleissner 1·50, and San Fernando 2·00 shillings in each case.

The Determination by Means of X-Rays of Minerals, Ores, and some Industrial Products. R. van Aubel. (Revue de l'Industrie Minérale, 1928, No. 176, Apr. 15, pp. 163–170 ; May 1, pp. 189–195). The author discusses the theory and practice of the X-ray examination of materials, and describes some of the metallurgical uses to which it has been applied.

A Furnace for Agglomerating Pulverulent Products. O. Lepersonne. (Revue Universelle des Mines, 1928, Vol. 18, May 1, pp. 124 -130). The author first discusses the angle of repose of powdered materials, and shows that for the general run of materials this angle is about 30°. This fact is made use of in the furnace described. The hearth is inclined at 30° to the horizontal, the lower part being slightly less steep. The material is fed in at the top and forms a thin layer right to the bottom of the furnace, the layer becoming thinner where the slope of the hearth is decreased. The flames from the burners are directed upon the extreme edge of the layer of material, so that the material is actually heated in very thin layers. The earlier discussion of the angle of repose shows how, as the material at the bottom is removed either by melting and dropping off the hearth or by other means, the powder automatically feeds itself from the feed-hopper. Details of the arrangement of the furnace are given.

REFRACTORY MATERIALS.

The Standards Report for the American Ceramic Society. (Journal of the American Ceramic Society, 1928, Vol. 11, June, pp. 331–534). This issue contains the Report of the Committee on Standards of the American Ceramic Society and consists of a collection of standard definitions, specifications, tests, and description of testing apparatus for all classes of refractory materials.

Developments in Refractory Materials. A. B. Searle. (Fuel Economy Review, 1928, Vol. 7, pp. 65–71).

Refractories, their Manufacture and Applications. J. F. Hyslop. (World Power, 1928, Vol. 10, Aug., pp. 137–144 ; Sept., pp. 253–257). The author surveys the characteristics of the chief refractory materials, silica and silica-alumina, and illustrates the main factors which determine their service, behaviour, and uses. A study is also made of temperature-property characteristics. Questions of strength, corrosion, thermal and electric properties, are considered.

Recent Investigation on Refractory Materials and their Application to Fuel Economy. A. B. Searle. (Fuel Economist, 1928, Vol. 3, May, pp. 535–537 ; June, p. 607).

Determination or Calculation of Refractoriness ? C. J. van Nieuwenburg. (Feuerfest, 1928, Vol. 4, Sept., pp. 138–141 ; Oct., pp. 156–157). The author discusses the chemical and physical changes which occur in refractories when they are heated to their softening points, and puts forward a correlation of all these characteristics.

Effect of Reducing Gases on the Transverse Strength of Fireclay Bricks. A. E. R. Westman. (Journal of the American Ceramic Society, 1928, Vol. 11, Aug., pp. 633–638). It was reported that fireclay brick, when heated in the presence of carbon monoxide, was disintegrated by the progressive deposition of finely divided carbon at the " iron spots " in the brick. The conditions necessary for the occurrence of this phenomenon were not definitely known, although the known reversibility of the catalytic reaction around 650° C. and the outcome of small-scale experiments indicated that disintegration would not occur above this temperature. To obtain more definite

information on this score, the effect of city gas at 550° C. and 1100° C. on the transverse strength of three brands of fireclay brick was determined. No significant changes in strength occurred at 1100° C. At 550° C. two of the brands suffered very significant decreases in strength, but the other brand was unaffected, although it had the highest iron content.

Measurement of the Expansion of Refractory Material up to 1600° C. K. Endell and W. Steger. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 721–724). An apparatus is described and illustrated with which the expansion of refractory bricks up to 1600° C. can be measured. Fireclay bricks with a medium or high alumina content show a very slight expansion up to 1300°, from which point they begin to shrink. Such bricks, if they contain much quartz, show the irregularities due to the quartz transformations—that is, they expand considerably up to 1450° and shrink if heated above that temperature. Magnesite bricks show a regular and considerable expansion up to 1500° and then a slight shrinkage. Silica bricks with a specific gravity of 2·35 do not expand after passing 600°, and such bricks with a specific gravity of 2·40 are constant in volume up to 1450°. Silica bricks, not so thoroughly fired, with specific gravities from 2·45 to 2·54, expand beyond 1250°, and at 1600° show a total linear expansion of 2·85 to 3·35 per cent.

The Thermal Expansion of Fireclay Bricks. A. E. R. Westman. (Illinois University, Engineering Experiment Station, 1928, Bulletin No. 181). The results are reported of an investigation of the thermal expansion and correlated properties of twenty brands of fireclay brick in the temperature range 25° to 950° C. Information concerning the mineralogic composition was obtained by petrographic methods and from chemical analyses submitted by the manufacturers. The thermal expansion curves obtained were classified on the basis of the presence or absence of certain characteristic inflections in the curves. The customary explanation for these inflections, namely, that they were due to the inversion of cristobalite and quartz present in the bricks, was subjected to a quantitative test by calculations based on the curves, the petrographic data, and the chemical analyses.

Methods for Measuring Thermal Conductivity of Insulating and Refractory Materials. M. L. Hartman and O. B. Westmont. (Paper read before the American Society for Testing Materials, June 1928).

How to Minimise Disintegration of Refractories due to Spalling. S. M. Phelps. (American Refractories Institute, Bulletin No. 24; Iron Trade Review, 1928, Vol. 83, Aug. 23, pp. 450–451, 482). A non-technical discussion of causes and remedies for mechanical, structural, and thermal spalling.

A Comparison of the Properties and Industrial Durability of Lime-Bonded and Clay-Bonded Silica Bricks. W. J. Rees and W. Hugill. (Paper read before the Ceramic Society, Sept. 1928). In the roofs of acid open-hearth furnaces there is no discernible difference in the durability of clay-bonded and lime-bonded bricks. In basic open-hearth furnaces there is a slight difference in favour of lime-bonded bricks. In electric steel melting furnaces the trials indicate increased durability of clay-bonded bricks as compared with normal lime-bonded bricks. In coke-ovens the durability of clay-bonded bricks is indistinguishable from that of normal lime-bonded bricks. The trials indicate that the clay-bonded brick is as resistant to salt corrosion and mechanical wear as lime-bonded bricks of the same grading and heat treatment.

Silica and Fireclay Refractories. A. T. Greene. (Paper read before the Manchester and District Junior Gas Association : Gas World, 1928, Vol. 188, May 19, pp. 501–502). A brief discussion of the properties of silica and fireclay refractories, with special reference to their use in the carbonising industry.

Brown Silica Bricks. W. Grum-Grjimailo. (Feuerfest, 1928, Vol. 4, July, pp. 105–106). The author considers that the American insistence on the use of very pure and coarse quartzite for making silica bricks does not lead to the best results. He mentions that in his tests on black silica bricks (SiO_2 80·15, FeO 14·83, MnO 0·18 per cent.), the bricks when placed in the gas ports of an open-hearth furnace withstood a temperature of 1710° C. very well ; an iron slag ran out of the test-pieces, and the tridymite crystals, grown together in skeleton form, remained behind. He then describes the production of a new type of silica brick at the Tschussowski Works in the Urals (Russia) ; the product formerly made by this firm is outlined and the difference in manufacture and improved qualities of the new (brown) bricks are indicated. The principal manufacturing difference lies in the addition to the mixture of $2\frac{1}{2}$ per cent. of basic open-hearth slag, powdered charcoal, and 2 per cent. of milk of lime. The resulting bricks are chocolate coloured, and have the following chemical composition : SiO_2 93·68, Al_2O_3 0·19, Fe_2O_3 2·31, CaO 3·21, MgO 0·25, MnO 0·38 per cent. (P_2O_5 not estimated). Comparative tests in an open-hearth furnace demonstrated their superior wearing properties over ordinary silica bricks. The author briefly discusses the reasons for their better behaviour.

On the Question of the Tridymitisation of Quartzite. P. P. Budnikoff. (Feuerfest, 1928, Vol. 4, Sept., pp. 136–138). Experiments are described which show that phosphorite with low phosphoric acid content can also be used to catalyse the conversion of quartzite into tridymite.

Bricks showing Brownish-Black Stains. H. Luftschitz. (Ton-industrie-Zeitung, 1927, Vol. 51, May 18, pp. 702–703). The author examined a brick in which were visible, both within and without, black points, around which were a red coloration and a part fused in the form of a crater. Analyses showed that the black parts contained nearly twice as much iron as the red parts, the iron in the former being present chiefly in the ferrous state. It was not possible to determine how the enrichment of these parts in iron was brought about.

Kaolinic Refractories and their Properties. M. J. Terman. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 814–815 ; Heat Treating and Forging, 1928, Vol. 14, June, pp. 642–643). The composition and properties of a new type of refractory recently introduced are described. Although the refractory qualities of the kaolinic materials have been known in the past, they have not previously been employed on account of the difficulty of processing them. The silica-alumina ratio is not an unusual one (SiO_2 51·96, Al_2O_3 45·38 per cent.), but the purity of the material results in a high melting point (3200° F. in oxidising and 3165° F. in reducing atmosphere). The thermal expansion is small, and the refractory does not "grow" under continual heat.

A Laboratory Furnace for Testing Resistance of Firebrick to Slag Erosion. R. K. Hursh and C. E. Grigsby. (Illinois University, Engineering Experiment Station, 1928, Circular No. 17). The furnace described is cylindrical, and is supported vertically on rollers, being rotated about its axis during a test. It is heated by a blast-burner using town gas and air, both at high pressure. Powdered slag is fed at a uniform rate through the burner, and impinges with the blast on the vertical faces of the bricks which form the lining of the furnace chamber. The melted slag flows down over the faces of the bricks and out through a port in the centre of the furnace bottom. The advantages of this type of furnace and method of testing are enumerated.

Some Common Abuses of Firebrick. L. S. Longenecker. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 809–811). Special attention is directed to two features in furnace construction that impose unduly severe conditions on the firebricks—namely, irregular joints and the keyed sprung arch roof. The manner in which these features affect adversely the refractory material and the methods of avoiding their ill effects are described. The author considers that when due allowances are made the suspended arch roof should be very little more expensive to install than the keyed sprung arch roof.

Note on the Arches of Furnaces, D. J. Delmotte. (Chaleur et Industrie, 1928, Vol. 9, May, pp. 232–234). The author discusses

the causes which provoke or hasten the destruction of the arches in furnaces.

New Developments in Gasworks Carbonising Plant, with Special Reference to Refractory Materials. G. M. Gill. (Paper read before the Ceramic Society : Gas Journal, 1928, Vol. 182, May 16, p. 447).

Investigations into the Destruction of Blast-Furnace Structural Materials, in Particular of Fireclay Bricks. E. Diepschlag and K. Feist. (Feuerfest, 1928, Vol. 4, July, pp. 106–108). The conclusion of a previous article (*see* Journ. I. and S.I., 1928, No. I. p. 724). The present instalment gives the results of "alkali fusion tests" and explains the meaning to be attached to these results.

Investigations into the Destruction of Blast-Furnace Linings by Carbon Monoxide. E. Diepschlag and K. Feist. (Feuerfest, 1928, Vol. 4, Sept., pp. 133–136). The authors first review the work of previous investigators on the destruction of blast-furnace linings and then describe their own experiments, from which it was concluded that the cause of the destruction of the linings is to be attributed to the precipitation of carbon from carbon monoxide gas, which reaction is considerably hastened by the presence of catalysts.

Dissociation of Carbon Monoxide in Contact with Refractory Materials. D. W. Hubbard and J. W. Rees. (Paper read before the Ceramic Society, 1928). Bricks from the upper part of a blast-furnace, where the temperature does not exceed 500° to 600° C., were found to contain deposits of carbon several inches away from the hot face. This was assumed to be the result of the dissociation of carbon monoxide, and the results of an investigation carried out to discover the probable causes of this carbon deposit are presented.

Silica Brick in the Open-Hearth Furnace. B. M. Larsen. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 803–807). The author has investigated the changes that take place in silica brick under conditions that are met with in service, particularly in the open-hearth furnace roof.

Refractories and the Open-Hearth. J. R. Miller. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 807–808). A brief review of the adverse conditions to which open-hearth wall and roof linings are subjected, with comments on the best methods of minimising their effects.

On Transformation Phenomena of Silica Bricks in the Crowns of Open-Hearth Furnaces. W. Grum-Grjimailo. (Feuerfest, 1928, Vol. 4, Aug., p. 125).

Permeability to Gas of Silica Bricks, Mortar Joints, and Masonry, in the Open-Hearth Furnace. H. Bansen. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 687–692). By means of a series of careful tests it was found that the permeability of masonry in walls of open-hearth furnaces and regenerators by gas is almost entirely due to cracks in the mortar joints. The permeability of the bricks themselves is negligible. By determining the carbon dioxide content of the air entering the furnace, it was possible to calculate the gas losses between the gas and air chambers, the results corresponding with the losses found by direct experiment. The leakage increases as the furnace gets older. Trial was also made with a wall built of bricks the surfaces of which had been ground true and fitted without mortar, but the leakage of gas was three times as great as when mortar was used.

Behaviour and Properties requisite in Steelworks Dolomite. O. Jacobs. (Stahl und Eisen, 1928, Vol. 48, July 26, pp. 993–995). For the basic converter the dolomite should possess constancy of volume and should contain no carbon dioxide which can be driven off by sharp burning. In burning, the dolomite should not be brought to sintering point, but the dolomite grains in the tar-dolomite mixture should be left in a condition in which they can absorb the tar oils while in storage. The sintering point should be sufficiently low to allow the dolomite grains to fuse together at the temperatures of charging the converter, otherwise the tar will be taken out of the lining to a certain depth. Amorphous dolomite is to be preferred to crystalline, because, although it may not be of the most suitable composition, its properties are of a uniform character in every way, which is not the case with crystalline, and this quality is of importance as regards its fusibility.

On a New Checker Brick, Specially for Open-Hearth Regenerators. K. Kniepert. (Stahl und Eisen, 1928, Vol. 48, Apr. 26, pp. 548–551). The bricks described are moulded with two opposite sides sloping ; the top and bottom faces are 190 mm. sq. and the bricks are 100 mm. high, but the top face is 20 mm. out of plumb with the bottom. A 70-mm. sq. hole passes through the brick, also at the same angle to the vertical. The advantages of the new form of brick, such as ease of manufacture, simplicity of installation, durability of the resulting checkerwork, high thermal efficiency on account of the eddies set up in the gas streams, &c., are dealt with very fully, and some test results are given.

Refractory Materials for Electrical Metallurgical Furnaces. A. B. Searle. (Iron and Steel Industry, 1928, Vol. 1, July, pp. 313–316 ; Aug., pp. 343–345). The author discusses the essential characteristics of refractory bricks used in electric steel-refining furnaces.

Refractories for the Cupola. W. Holland. (Paper read before the Institute of British Foundrymen, Apr. 17, 1928 : Foundry Trade Journal, 1928, Vol. 38, May 24, pp. 367–368).

The Insulation of Open-Hearth Furnace Regenerators. L. B. McMillan. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 257–262). The advantages to be derived from the use of insulated checker chambers are pointed out, and graphs are given showing the heat losses through uninsulated and insulated walls and roofs of regenerators for various thicknesses of brick and for various thicknesses of insulation. A typical insulated checker chamber is illustrated, showing the thickness of insulation used on the various portions of the chamber.

Economy in Insulating Furnace Arches. (Heat Treating and Forging, 1928, Vol. 14, Oct., pp. 1202, 1206). The tests reported demonstrate the economy to be derived from the addition of insulating bricks to the arch of a furnace. The arch (area, 200 sq. ft.) was of 9-in. firebrick, and the insulating bricks were $2\frac{1}{2}$ in. thick ; with an interior temperature of $1200°$ C. the temperature of the outside of the firebrick was $219°$ C. when unprotected and $645°$ C. when insulated. Costs are given to show that the saving obtained during the life of one arch was 188 dollars, the life being about 10 heats each of one month's duration.

Saving Heat Losses by Insulation. J. B. Fortune. (Fuel Economist, 1928, Vol. 3, Sept., pp. 763–766). A brief discussion of the insulation of open-hearth furnaces, mixers, and soaking pits.

Highly Refractory Furnace Linings. K. Heinrich. (Giesserei-Zeitung, 1928, Vol. 25, Sept. 1, pp. 508–513). The qualities required in high refractories, and the properties of artificial and natural bricks, are first discussed. The Crummendorf quartzite schists, their properties and possible applications, are next described. The large pieces, as mined, are cut into blocks by means of heavy saws with diamond teeth attached, while the smaller pieces are ground and made into mortar and into a paste for moulding into bricks. When laying the blocks, care must be taken that the ends, and not the sides of the blocks cut parallel to the cleavage planes, will be subjected to the action of the fire.

FUEL.

PROPERTIES, PREPARATION, MANUFACTURE, AND USES.

FUEL TECHNOLOGY.

National Fuel and Power Committee. (Colliery Guardian, 1928, Vol. 137, Sept. 28, pp. 1221–1224 ; Oct. 5, pp. 1331–1333). The Board of Trade has recently published the first report of the National Fuel and Power Committee, which, on the recommendation of the Samuel Commission, was appointed on August 20, 1926, " to consider and advise upon questions connected with the economic use of fuels and their conversion into various forms of energy, having regard to national and industrial requirements, and in the light of technical developments." A summary of the Committee's conclusions and recommendations is given.

The New Point of View in the Utilisation of Bituminous Coals. C. Berthelot. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, June, pp. 322–330). The author reviews the principal points of note which were made apparent at the first International Conference on Bituminous Coal at Pittsburgh. He deals with the subject under the following headings : carbonisation of coal, gasification of coal, pulverised coal firing, utilisation of heat in modern steelworks, and chemical use of coal.

Industrial Heating by Solid, Liquid, and Gaseous Fuels. Sir R. Hadfield, Bt., and R. J. Sarjant. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, pp. 620–621 ; Nov. 2, pp. 652–653 ; Nov. 9, p. 694). A general survey of heating problems in the iron and steel industry.

Recent Developments in Fuel Technology in Iron and Steel Practice. E. C. Evans. (Fuel Economy Review, 1928, Vol. 7, pp. 50–55).

Fuel Economy Development in the Iron and Steel Industry. J. B. Fortune. (Fuel Economist, 1928, Vol. 4, Oct., pp. 41–43).

Utilisation of Solid and Liquid Fuels. C. H. Lander. (Paper read before the Engineering Conference of the Institution of Civil Engineers : Iron and Coal Trades Review, 1928, Vol. 116, June 1, p. 833).

The Fuel Industries and the Work of the Chemical Engineer. Sir Arthur Duckham. (Paper read before the Chemical Industry Conference, May 14, 1928 : Chemistry and Industry, 1928, Vol. 47, May 18, pp. 519–521). A brief discussion of the importance of the chemical engineer in the following phases of the fuel industry : (1) The getting and raising of coal and its preparation for the market ; (2) the carbonisation of coal ; (3) the production of oils from coal ; (4) manufacture of pig iron ; (5) the manufacture of steel up to the billet form ; (6) the use of coal for the production of industrial heat and power ; and (7) the heating of kilns and furnaces in general.

Second Exhibition of Industrial Heating. (Chaleur et Industrie, 1928, Vol. 9, June, pp. 271–375). This number is almost exclusively devoted to descriptions (in many cases illustrated) of the products of the exhibitors at the Second Exhibition of Industrial Heating held between June 23 and July 8, 1928, in Paris.

Utilisation of Heat in Metallurgical Works. L. H. Stchepine. (Chaleur et Industrie, 1928, Vol. 9, May, pp. 217–222). The author discusses mathematically the heat requirements of coke-ovens, blast-furnaces, and open-hearth furnaces.

Balancing Heat and Power in Industrial Plants. R. V. Kleinschmidt. (Paper read before the American Society of Mechanical Engineers, Dec. 1928). The purpose of this paper is to indicate the importance of various factors in increasing the amount of by-product power that can be generated in industrial plants using process heat. It is shown that there are opportunities for economies in increased boiler pressures, high superheats, and particularly by reducing the back pressure on turbines and engines to the lowest possible point. Utilisation of waste heat from heating furnace gases offers an opportunity for additional power generation in mixed-pressure turbines or in low-pressure condensing turbines. It is shown that hot air can be most economically used by returning it to the boiler furnace, and by heating air for process work with exhaust steam.

Two curves are presented which give the results of a detailed analysis of the problem of water heating, one showing the advantages of two-stage water heating as compared with heating by exhaust steam only, and the other giving the best condenser vacuum for various initial and final temperatures of water in a two-stage process. Attention is called to the importance of an adequate study both of the heat and power requirements of the process, and of possible alterations of process as a basis for the improvement of the heat-power balance.

Sodium-Peroxide Bomb Calorimeter. (Engineering, 1928, Vol. 125, May 18, p. 623). In 1900 Professor Parr described a new bomb calorimeter in which the gaseous oxygen was replaced by sodium peroxide. The bomb had, however, the old disadvantage that its outer walls were in contact with the calorimeter water from the start of operations, so that cooling took place from the very commencement. In the new type of bomb described this is overcome by the use of a nickel-chrome steel container inside the bomb, the bottom of the latter being perforated. At first the container is surrounded by a jacket of air; the firing of the charge heats the air and expels it through the bottom perforations, and then, as the bomb is cooled again by the water, the latter flows into the annular space into contact with the container. The bomb is rotated at 150 r.p.m. in the water in the calorimeter. The coal sample, about 0·5 grm., is mixed with about 15 grm. of Na_2O_2 and 1 grm. $KClO_4$, and the mixture is fired electrically.

Furnace Volume and Combustion. H. Jacobs. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1216–1217). The necessity for the provision of adequate furnace volume to permit of efficient combustion is pointed out; the question of suitable refractories and other matters concerning combustion in a boiler firebox are also touched upon.

Fuel Control. H. C. Armstrong. (Fuel Economist, 1928, Vol. 3, May, pp. 505–509; June, pp. 569–571; July, pp. 639–641; Aug., pp. 705–707). The continuation of a series of articles in which the author surveys the chief factors in the lowering of fuel costs in steelworks. (*See* Journ. I. and S.I., 1928, No. I. p. 735.)

Discussion of the Elements Entering into the Cost of Producing Power. W. B. Skinkle. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 278–290). The author presents an analysis of the elements entering into the cost of the production of steam and electric energy.

The Present Trend in Boiler Practice. W. H. Patchell. (Paper read before the Institution of Civil Engineers, June 5, 1928 : Iron and Coal Trades Review, 1928, Vol. 116, June 15, pp. 906–907). The modern tendency in boiler practice appears to be the development of still larger steam generating units, which will utilise to better advantage the space they occupy, and for still higher steam pressures. The air heater is coming into use in power stations, either as auxiliary to, or to supplement, economisers where the feed-water is being heated by steam bled from the main turbines. Designs for the higher steam pressures have so far developed that boilers with a working pressure of 800 lb. per sq. in. are now being made without any rivets; the drums are hollow forged, and all joints are made by expanding.

The Trend of Power Plant Design. F. H. Daniels. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 790–793). The author discusses the trend in design of modern power plant, pointing out that increased boiler pressure and higher degrees of superheat have brought about improvements in the design of boiler settings and in the methods of burning fuel.

High Pressure Steam Boilers. G. A. Orrok. (Paper read before the American Society of Mechanical Engineers: World Power, 1928, Vol. 10, July, pp. 17–25; Blast-Furnace and Steel Plant, 1928, Vol. 16, Oct., pp. 1332–1336). After referring to the work of Münzinger, Hartmann, and Mellanby and Kerr, the author discusses the lines of further investigation which offer the most promise. In so doing he considers the effect of tube inclination; the circulation problem; releasing surface and steam space; safety in operation; increase in capacity; boiler materials; temperature margins; and stresses in superheater tubes, riveted drums, and headers.

Steam Generation in Sweden. (World Power, 1928, Vol. 10, Sept., pp. 257–258). A brief review of recent Swedish practice in steam generation, with reference to developments in air preheating and operation at increased temperatures and pressures.

Boiler-House Operation. M. G. Wallace. (Fuel Economist, 1928, Vol. 3, Sept., pp. 743–745; Vol. 4, Oct., pp. 21–24). A series of articles dealing with boiler-house operation. The character and composition of fuels are discussed.

Power-House Measurements. (World Power, 1928, Vol. 9, pp. 290–292; June, pp. 355–356; Vol. 10, July, pp. 50–52; Aug., pp. 164–166; Sept., pp. 271–274). A series of articles dealing with the use of measuring, indicating, and recording instruments in power-houses. Various types of combustion control apparatus also described.

The " Hagan " System of Automatic Boiler Control. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 12, p. 535). The arrangement of the " Hagan " system of combustion control for boilers is described.

Automatic Combustion Control. J. E. O'Breen. (Proceedings of the Cleveland Institution of Engineers, 1927–28, pp. 178–202). A discussion of the design, types, and application of automatic combustion control apparatus.

Physical Properties of Fuels. H. H. Lewis. (Engineering and Boiler-House Review, 1928, Vol. 42, Oct., pp. 204, 209). A preliminary article of a series dealing with the economical operation of steam boiler plants.

The Economical Use and Generation of Steam on Industrial Plants.
R. Hattersley. (Fuel Economy Review, 1928, Vol. 7, pp. 42–45).

Air Infiltration in Boiler and Furnace Practice. H. Edwards.
(Fuel Economist, 1928, Vol. 3, Aug., pp. 685–687). The causes and
prevention of air infiltration, and its influence on efficiency, are
discussed.

The Benson High-Pressure Boiler. (Iron and Coal Trades Review,
1928, Vol. 117, Sept. 7, p. 327). A short account is given of the arrange-
ment of this boiler, which is designed for firing with pulverised fuel.

Firing of Gas and Pulverised Coal. F. G. Cutler. (Paper read
before the American Society of Mechanical Engineers, May 1928 :
Blast-Furnace and Steel Plant, 1928, Vol. 16, July, pp. 927–930, 935).
Operating results obtained at the boiler plant of the Tennessee Coal,
Iron, and Railroad Company are presented. The boilers are arranged
to be fired with either blast-furnace gas or pulverised coal, or a
combination of both fuels at the same time.

Four Fuels Burnt Under Boilers. J. R. Miller. (Blast-Furnace and
Steel Plant, 1928, Vol. 16, June, pp. 787–789, 793). The power plant
equipment at the blast-furnace power-house of the Otis Steel Company
is described. The boilers are so designed that blast-furnace gas,
pulverised fuel, coke gas, or oil fuel may be utilised.

Steel Plant Boiler Firing Flexible. C. Longenecker. (Blast-Furnace
and Steel Plant, 1928, Vol. 16, June, pp. 780–783, 793). Particulars
are given of the boiler plant of the Central Alloy Steel Corporation.
Five boilers are arranged to burn either powdered coal or blast-furnace
gas, and one boiler is equipped with a chain grate stoker, on which coke
breeze is burned. Steam is utilised for the production of power for
driving the mills, and air for blowing the blast-furnaces. Conversion
is accomplished through one 10,000 kw. turbo-generator, and two
turbo-blowers with a capacity of 50,000 cu. ft. per minute. Operating
tests on the plant are tabulated.

A Combined Boiler and Producer Plant. C. Longenecker. (Blast-
Furnace and Steel Plant, 1928, Vol. 16, May, pp. 642–645). An
illustrated description is given of the boiler and producer plant of the
Sharon Steel Hoop Co. There are two 500 H.P. Stirling boilers and
four 10-ft. diameter Morgan producers all housed under one roof, which
has greatly reduced the labour required for supervision and coal
handling. The boilers are fired with producer-gas.

Boiler-House Possesses Unusual Features. C. Longenecker. (Blast-
Furnace and Steel Plant, 1928, Vol. 16, Aug., pp. 1072–1075). The

new power plant of the Truscon Steel Co. is described, special attention being given to the storage and handling of the fuel. The coal is stored in silos, and is conveyed to the boilers by means of a truck attached to a conveyor chain ; electrical contacts stop the truck at each end of its track.

Supermiser Installation at Wigan Ironworks. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 17, pp. 221–222). Particulars are given of the supermiser installation at the works of the Wigan Coal and Iron Co., Ltd., where steam is raised in a battery of 14 Lancashire boilers. The boilers are arranged in a coupled battery, and for the purpose of the installation the batteries are treated as separate units, each being supplied with its own supermiser interposed between the boilers and the chimney. The boilers are fired with blast-furnace gas. In the supermiser use is made of concentric tubes, the hot gases passing through the annular space between the inner and outer tubes, the feed-water passing through the inner tubes, and the air for combustion sweeping over the outer surface of the outer tubes. The supermiser for each battery of boilers is 17 ft. long between tube plates, 8 ft. 6 in. in diam., and contains 258 water tubes of 2-in. bore and 261 gas tubes 4 in. in diam. The cleanliness of the gas-heated surfaces is found to be amply assured, owing to the velocity of the gas flow, which at the inlet end of the tubes is about 75 ft. per second. The high gas velocities are obtained by an induction fan. The blast-furnace gases from the boilers enter the supermiser at a temperature of approximately 1000° F. and leave at 250° F. The temperature of the outgoing air is never less than 500° F. The boilers are fitted with Hunter " S " type gas burners, illustrated details of which are given.

The Steam Accumulator. (Iron and Steel Industry, 1928, Vol. 1, June, pp. 295–296). The Ruths steam accumulator is described shortly, and brief particulars of several installations are given.

Coal and Ash Handling for Steel Plants. H. S. Ford. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Aug., pp. 1070–1071, 1075). The simplicity and durability of devices in which steel cables are used are pointed out ; the skip hoist and the cable drag scraper are discussed.

Trials in the Determination of the Coefficient for Heat Transfer from Air and Gases of Combustion in Tubes. E. Schulze. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 223–244).

Considerations on the Theory of Regenerative Furnaces. J. Seigle. (Génie Civil, 1928, Vol. 92, June 9, pp. 557–562 ; June 16, pp. 588–589).

A Recuperator Unit for Industrial Furnaces Burning Oil. A. E. Walden. (Iron and Steel Engineer, 1928, Vol. 5, July, pp. 334–335).

The Calculation of Regenerators. W. Heiligenstaedt. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 217–222). Heat interchange is first discussed mathematically, and the method of calculating its value is then described and explained by means of examples.

The Functions of Regenerators in Relation to the Refractory Materials of Construction. A. T. Greene. (Paper read before the Ceramic Society : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 5, p. 492 ; Oct. 12, pp. 533–534). The subject is discussed under the following headings : thermal efficiency of regenerators ; design of regenerators ; published data about regenerators ; height of regenerators ; efficiency of regenerators ; properties of refractories for open-hearth furnace regenerators ; variation of specific gravity with temperature ; rate of passage of heat through brickwork ; summary of thermal properties ; and selection of refractories.

Heat and Temperature Flow in Walls of Any Shape. K. Lachmann. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 11, pp. 1127–1128). The author describes a method for computing the flow of heat in walls of any shape whatever by mathematical means.

The Flow of Heat through Furnace Hearths. J. D. Keller. (Fuels and Furnaces, 1928, Vol. 6, June, pp. 743–752). The author presents calculations of the flow of heat through solid or non-ventilated types of hearths. Formulæ and examples are given for circular hearths, very long hearths with parallel sides, and square or rectangular hearths.

Measurement of Steam Quantity in Works Practice. J. L. Hodgson. (Journal of the Institute of Fuel, 1928, Vol. 2, Oct., pp. 17–32). The author describes the construction and installation of several forms of steam meter, the precautions to be taken in their use, and the computation from their readings of the total steam used over a given period.

Fuel Economy in Blast-Furnace Plants. J. B. Fortune. (Fuel Economist, 1928, Vol. 3, May, pp. 509–513 ; June, pp. 571–575 ; Aug., pp. 708–711). The continuation of a series of articles dealing with some of the aspects of the fuel problem as related to blast-furnaces and their auxiliary equipment. The efficient heating and insulation of blast-furnace stoves and arrangement of the checkerwork are discussed. (*See* Journ. I. and S.I., 1928, No. I. p. 780.)

Fuel Control of Hot-Blast Stoves. J. B. Fortune. (Journal of the Institute of Fuel, 1928, Vol. 2, Oct., pp. 116–126). The subject is discussed under the following headings : Composition of blast-furnace gas ; physical characteristics of blast-furnace gas ; gas cleaning ; and combustion of blast-furnace gas. The different types of gas burners and controllers are shown. The utmost refinement in

combustion control necessitates the supply of combustion air under pressure, automatic control to maintain a constant ratio of gas and air, an efficient premixing burner, and continual checks upon combustion by the use of CO_2 and CO continuous recorders coupled up to the stove connection to the chimney flue.

Fuel Control in Open-Hearth Practice. J. L. Bentley. (Journal of the Institute of Fuel, 1928, Vol. 2, Oct., pp. 104–108). A number of graphs show the economies effected in fuel consumption in open-hearth furnaces by close control of gas quality and pressure, control of air supply through the valves, and control of draft. Control of these essentials leads to an increase in the calorific intensity of the flame, and will have the following results : (a) Saving in fuel; (b) increased output of steel ; (c) longer life of furnaces (because of less variation in the temperature at which they are operated) ; (d) lower velocity of gas passing through the furnaces, and consequently lower brick costs ; (e) less cost of deoxidisers, and improvement in quality of the steel produced.

Fuel Control in Forge and Rolling-Mill Practice. H. C. Armstrong. (Journal of the Institute of Fuel, 1928, Vol. 2, Oct., pp. 109–115). The weekly data required for systematic control are not great, and need not consist of more than : (a) Fuel used ; (b) material heated or produced ; (c) furnace hours during which the heating continues. From these are calculated : (d) Fuel per unit weight (ton) of output ; (e) output per furnace-hour ; (f) fuel per furnace-hour. Several characteristic curves are produced showing the relation between the " fuel per hour " and the " output per hour." The method of computing the output is of less importance for shop control, and it is sufficiently accurate to plot the production figures. The results of a number of tests covering the whole firing operation of a heating furnace are shown by means of a graph. The control of steam consumption as an aid to fuel economy is also discussed.

The Development of Automatic Temperature Control for Industrial Heating Apparatus. A. N. Otis. (Fuels and Furnaces, 1928, Vol. 6, Oct., pp. 1387–1394, 1398).

Recording and Controlling Instruments in the Iron and Steel Industry. C. C. Eagle and R. M. Walker. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 263–277). The authors discuss the use and value of recording and controlling instruments in various departments of an iron and steel plant.

Waste-Heat Recovery. F. J. Bailey, W. Gregson, and J. W. Reber. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas Journal, 1928, Vol. 184, Oct. 10, pp. 130–131).

The Utilisation of Waste Heat for Steam Raising. G. Martin. (Transactions of the Ceramic Society, 1927–28, Vol. 27, pp. 222–242). A description is given of recent technical advances achieved in the utilisation of waste heat and the transmission of heat through tubes.

Waste-Heat Recovery from Open-Hearth. T. J. Ess. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 646–648). A brief discussion from the theoretical and practical viewpoints of waste-heat boiler practice.

The Dew Points of Waste Gases and their Importance for Waste Heat Feed-Water Heaters. A. Sauermann. (Glückauf, 1928, Vol. 64, Sept. 8, pp. 1211–1215). If the temperature of the incoming water in waste gas feed-water heaters lies below the dew point of the waste gases trouble will arise, as the deposition of the water vapour will cause rusting to occur, thus damaging the heater tubes. In order to determine the temperature at which the feed-water should enter the heater, an investigation of the principal fuels with regard to their composition, their water content, and the humidity and degree of excess of the air for combustion, was undertaken. An example of the method of calculation is given, and the results are discussed.

Factors which Influence the Choice of Waste-Heat Boilers. J. B. Crane. (Iron and Steel Engineer, 1928, Vol. 5, Sept., pp. 407–412). If the pressures, weight, and character of gases are suitable, the return tubular boiler will give the maximum results for the least outlay. If the conditions are not suitable for return tubular boilers, a vertical boiler is the most suitable. The single pass horizontal boiler is suitable for special conditions, and may be used in some cases in place of vertical boilers.

Waste-Heat Boilers and the Efficient Utilisation of Exhaust Steam. G. E. Hider. (Iron and Coal Trades Review, 1928, Vol. 116, June 15, p. 897). A short discussion of the factors to be considered in the installation of waste-heat boilers in steelworks.

The "Recovery" Smoke Tube Waste-Heat Boiler. (Iron and Coal Trades Review, 1928, Vol. 116, June 22, p. 941). A short account is given of a waste-heat boiler of the horizontal type, fitted with inclined tubes. It is designed to carry the highest pressures and is capable of dealing with all kinds of waste gases. The boiler requires no brickwork settings or foundations other than a concrete base.

Cost of Heating (Workshops, Offices, &c.) in Ironworks. H. Jordan and A. Schulze. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 699–706). The costs of warming workshops and halls in an iron and steel works in the winter months form an important item

1928—ii. s

in the overhead charges of the works. Calculations of such costs are given for different departments of a works, together with particulars and costs of the necessary installation.

Utilisation of the Water from Water-Cooled Parts of Furnaces, Engines, &c., for Supplying the Warm Water Requirements of a Works. A. Schulze. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 19–22). Heat economy in an ironworks may be promoted by utilising the heated water from the water-cooled parts of furnaces, gas-engine jackets, and stirrers of gas-producers for warming offices and supplying warm water to baths and lavatories. An arrangement of piping and storage tanks for carrying such a scheme into effect is illustrated and explained.

COAL.

Observations on the Theory of Formation of Mineral Oil and Coal. A. F. von Stahl. (Montanistische Rundschau, 1928, Vol. 20, Sept. 16, pp. 550–551). The fact that coal and brown-coal may be converted into products resembling mineral oils by hydrogenation under pressure at high temperatures leads the author to believe that the formation of coals and mineral oils took place under similar natural conditions. In the article he elaborates his theory.

The Microscopic Investigation in Relief Sections of Fine-Grained Products from the Preparation of Coal. E. Stach and F. L. Kühlwein. (Glückauf, 1928, Vol. 64, June 23, pp. 841–845). The authors prepare their specimens for micro-examination as follows : the fine material is stirred into a small quantity of melted resin ; the mass is then carefully warmed until it is very fluid, without any bubbles being allowed to form, and it is then cast on to a cold greased glass plate. The mass is then relief-polished in the same way as anthracite and banded coals. The structural constituents to be found in the dust, powder, and slimes examined are illustrated and discussed.

The Macrographic Structure of Saar Coking Coal. H. Hoffmann. (Glückauf, 1928, Vol. 64, Sept. 15, pp. 1237–1243 ; Sept. 22, pp. 1273–1280). The macroscopic constituents of Saar coals are characterised by their appearance and by their chemical and physical properties. Crucible coking tests on various mixtures of the constituents throw light on the adverse effect of the badly baking portions on the cokeability ; it was found that 25 to 30 per cent. of the coal charged into the coke-ovens consisted of material having injurious effects on the coking power.

Microstructure of New Zealand Lignites. W. P. Evans. (New Zealand Journal of Science and Technology, 1928, Vol. 9, Apr., pp. 339–359). The conclusion of a series of articles (*see* Journ. I. and S.I., 1928, No. I. p. 737). The present instalment completes the discussion of lignites subjected to the influence of igneous intrusions, and deals with lignite taken from the Mount Torlesse Co.'s mine at Broken River, North Canterbury.

Classification of Coal. (American Institute of Mining and Metallurgical Engineers, 1928, Technical Publication, No. 156). This publication contains the following papers, with discussions, dealing with various aspects of the problem of coal classification : C. A. Seyler— The Classification of Coal ; W. T. Thom, jun.—Classification of Coal from Proximate Analysis and Calorific Value ; H. J. Rose—Classification of Coals by Ultimate Analysis ; M. R. Campbell— Classification of Coal from the Viewpoint of the Geologist ; R. Thiessen—Classification of Coal from the Viewpoint of the Paleobotanist ; W. Francis— Classification of Coal in the Light of Recent Discoveries with Regard to its Constitution ; F. V. Tideswell and R. V. Wheeler—Pure Coal as a Basis for Classification ; F. R. Wadleigh—Commercial Classification of Coal ; E. McAuliffe and M. Macfarland—Classification of Coals from the Point of View of the Railroads ; W. H. Fulweiler—The Use Classification of Coal as Applied to the Gas Industry ; W. H. Blauvelt —Classification from the Standpoint of the By-product Coke Industry ; S. R. Flagg—Classification of Coal from the Standpoint of the Steam Power Consumer ; F. G. Tryon—Classification of Coal from the Standpoint of the Coal Statistician.

The Classification of Coal. S. W. Parr. (Illinois University, Engineering Experiment Station, 1928, Bulletin No. 180). After discussing the fundamental factors in coal classification, the author sets forth his system of classification. A bibliography of literature on the subject is appended.

Some Physico-Chemical Properties of Coal. F. M. Lea. (Fuel in Science and Practice, 1928, Vol. 7, Oct., pp. 431–443). A study has been made of certain physico-chemical properties of coals. The rate and amount of sorption of moisture by coals from a saturated atmosphere is a characteristic property of a coal. This property runs parallel to the oxygen contents of coals in which this content is less than about 10 per cent. In the coals of higher oxygen content no such correlation exists. The adsorption of dyes by coals depends primarily on the coal, and only in secondary degree on the nature of the dye. The adsorption is hydrolytic in type. There is no definite relation between sorption of dyes by coal and that of moisture or oxygen. The linear expansion of dry coals on wetting has been measured, and the effect of alkalis on this action investigated. The

oxygen absorption by a number of coals has been determined. In the presence of lime the rate is much increased. The 35 coals examined have, on the basis of the above properties, been divided into three classes. The bearing of these results on the colloidal structure of coal is discussed.

The Constitution of Coal. R. V. Wheeler. (Paper read at the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, p. 450).

Studies in the Composition of Coal. Oil-Yielding Constituents. R. Holroyd and R. V. Wheeler. (Journal of the Chemical Society, 1928, Oct., pp. 2669–2677). The paper records experiments on the slow destructive distillation *in vacuo* of bright coal (mixed vitrain and clarain) from the Wigan Six Foot seam. The main conclusions drawn are : (1) That the hydrocarbons and resins, extractable from the coal by organic solvents, yield a high proportion of the oils obtained on distillation, the former distilling unchanged quantitatively, the latter distilling partly and partly decomposing ; (2) that the coal has a definite decomposition point which is unaffected by the experimental conditions ; for the Wigan Six Foot coal it was 318° C. Characteristic products of this decomposition, which is of the ulmin constituents of the coal, are water and phenolic compounds. As soon as the decomposition point is passed, the character of the coal, as evinced by its behaviour towards solvents, its caking power, and its general reactivity, undergoes a sudden and marked change.

Researches on the Chemistry of Coal. Part V.—The Maturing of Coal Considered from the Standpoint of its Benzene-Pressure-Extraction. W. A. Bone, L. Horton, and L. J. Tei. (Proceedings of the Royal Society, 1928, Vol. 120A, pp. 523–545).

The Improvement of Coals by Heating. (Montanistische Rundschau, 1928, Vol. 20, May 16, pp. 285–292 ; June 1, pp. 321–328). The constitution of coals relative to their possibility of improvement by heating is discussed and details are given of experiments carried out, on the basis of which F. Brauneis has built up a method of improving coals by heating them, which is described.

Coal Conductivity Cell. E. Sinkinson. (Industrial and Engineering Chemistry, 1928, Vol. 20, pp. 862–865). The ohmic resistance of powdered coal can be measured with a fair degree of accuracy by using the specially designed cell described in the paper, in circuit with an ordinary Wheatstone bridge combination. The cell containing the coal is employed simultaneously with a standard cell, into which is placed coal, graphite, or charcoal, according to the type of measurement to

be made in the test cell. By this means comparative measurements of resistance can be made with any series of coals properly prepared, provided they are conductors of electricity.

A critical examination of the cell and method of using it has been conducted to determine its usefulness under varying conditions. It was found that concordant results can be obtained on the same sample, having regard to the character of the substance and the limits of accuracy of the method. The method may be used in the process of sampling, and for the comparison of samples before any other work has been done on them.

Measurement of the resistance of a coal before and after boiling with concentrated hydrochloric acid to remove the soluble portion of the ash shows that this treatment lowers the resistance of the coal from 12,730 ohms to 9360 ohms, by the removal of 1·40 per cent. of its ash.

The resistance of Pennsylvanian and Scotch coals has been compared.

Finally, the method has been used to clear up an anomaly previously found that the adsorption of carbon dioxide by a bituminous coal is greater than that by the fusain taken from it.

A Preliminary Investigation of the Nitrogenous Matter in Coal. C. W. Shacklock and T. J. Drakeley. (Journal of the Society of Chemical Industry, 1927, Vol. 46, Dec. 30, pp. 478–481T).

A Study of the Nature of Sulphur in Canadian Coal and Coke. J. H. H. Nicolls. (Canada, Department of Mines, Mines Branch, Investigations of Fuels and Fuel Testing, 1926, pp. 34–50).

Brown-Coal. (Fuel Economy Review, 1928, Vol. 7, pp. 2–13). The characteristics and properties of brown-coal, its occurrence and development within the British Empire, and its winning, drying, and briquetting are dealt with. The article is largely based upon the paper by Sir Richard Redmayne, which appeared in the Proceedings of the Institute of Fuel, Dec. 1926.

Pyritic Oxidation. H. Macpherson, N. Simpkin, and S. V. Wild. (Mines Department, London; Safety in Mines Research Board, 1928, Paper No. 47). A comparison is made of the behaviour on oxidation in the laboratory of the pyrites contained in coal taken from the Ravine seam, Lancashire, with the behaviour of the corresponding coal *in situ*. The authors conclude that, while the oxidisable pyrites contained in this coal may assist in a minor degree in the self-heating of the coal, the most important effect of the pyrites is evidently the disintegration caused in the coal by its oxidation and the greater bulk of the oxidation products.

Spontaneous Heating of Coal. J. D. Davis and D. A. Reynolds. (United States Bureau of Mines, 1928, Technical Paper 409). The results of chemical and physical research on the various factors that influence the spontaneous heating of coal are presented and critically examined. The process of spontaneous heating may be considered to take place in two stages. The first stage is operative at room temperature as soon as freshly broken coal is exposed to the air. It begins with the physical absorption of oxygen and is continued by the formation of a solid chemical compound of coal and oxygen, which is gradually decomposed as the temperature rises. Decomposition is not complete, however, until the temperature reaches about 445° F. The coal increases in weight by the amount of oxygen retained.

The second stage involves the breaking up of the solid compound of coal with oxygen and the formation of the final oxidation products—carbon dioxide, carbon monoxide, and water.

Dry Cleaning of Coal. H. Louis. (Fuel Economy Review, 1928, Vol. 7, pp. 12–16). The author outlines the developments in the dry cleaning of coal, and points out the advantages to be expected from this method of treatment. He is of the opinion that there is a field for dry cleaning and wet cleaning working side by side, and that neither method will wholly supplant the other.

The Cleaning of Small Coal. W. Chapman. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, pp. 452–453).

The Dry Cleaning of Coal. K. Appleyard. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, pp. 453–454 ; Colliery Guardian, 1928, Vol. 137, Sept. 28, pp. 1227–1230).

The Principles of Pneumatic Separation. G. Raw and F. F. Ridley. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Colliery Guardian, 1928, Vol. 137, Oct. 5, pp. 1325–1328 ; Oct. 12, pp. 1440–1442). The principles of pneumatic separation are discussed, and a description is given of the Static dry washing plant.

The Dry Cleaning of Coal. R. Genel. (Mémoires de la Société des Ingénieurs Civils de France, 1928, Vol. 81, Mar.–Apr., pp. 421–455). The author reviews the advantages of the dry cleaning of coal and relates its development. He describes recent progress made in the process in America and in England, and illustrates a variety of machines.

Separation of Ashes from Coal Dust. Gonell. (Archiv für die Wärmewirtschaft, 1928, p. 209 ; Glückauf, 1928, Vol. 64, Aug. 25, pp. 1158–1159). The author's apparatus for investigating the separa-

tion of ashes from coal dust by means of an air-blast is described. It consists of a brass cylinder with a cup-shaped base. The latter is connected to a glass attachment into which the material to be investigated is weighed. A tube leading to the bottom of the glass vessel introduces the air-blast, which carries the coal particles up to the top of the tube, where they settle on a plate under a glass bell; the ash particles settle down again in the glass attachment. The results of a variety of tests are reported, the conclusion from which is that with many types of coals complete separation is possible, but only where the constituents of the coals are distinct so that grinding shall produce particles which are either rich in ash or else poor; also the specific gravities of the ash and coal must be sufficiently diverse.

The Rational Cleaning of Coal. R. Lessing. (Journal of the Institute of Fuel, 1928, Vol. 11, Oct., pp. 5–16). The principles of the gravity separation process are outlined, and a description is given of the plant in operation at the Yniscedwyn colliery, together with particulars of operating results.

A New Dry-Cleaning Plant. (Colliery Engineering, 1928, Vol. 5, June, pp. 232–235). An illustrated account is given of the Etna separator installed at the plant of Baddesley Collieries, Ltd., together with some of the results obtained under test.

The Lockwood Dry Coal Cleaning Process. (Colliery Guardian, 1928, Vol. 137, Sept. 21, pp. 1121–1122). The process described is for the treatment of small coal from $1\frac{1}{2}$ in. downwards. The coal is treated on a deck which is inclined at an angle, longitudinally, to suit the coal, and by the oscillating motion imparted to it the coal and dirt are spread out over its surface. The resulting momentum given to the particles causes the material to be thrown rapidly forward against and between converging buffers which force the moving particles into narrower but deeper masses, the lighter particles thus mounting more easily and rapidly than the heavier ones. This " mounting up " operation is materially assisted by the application of a low pressure of air, playing against and into the mounting mass, which becomes aerated.

The mass is then divided by a horizontal adjustable diaphragm, the lighter clean coal passing over the top and thence into the clean coal launder. The heavier material passes under the diaphragm for the second stage of treatment.

The second treatment depends upon the differences in resiliency between the coal and foreign particles to bring about the separation between them.

Air Cleaning Plant embodies Some Unusual Features. W. H. Naylor and A. F. Brosky. (Coal Age, 1928, Vol. 33, May, pp. 270–272).

An illustrated account is given of a pneumatic cleaning plant for small coal in operation at an American colliery.

An Experiment with Anthracite Dust. C. Humphreys. (Colliery Engineering, 1928, Vol. 5, June, pp. 220–223). An account is given of a method for collecting the dust at a screening plant of an anthracite colliery and its utilisation under boilers.

On the Theory of the Washing Diagram. J. Finkey. (Montanistische Rundschau, 1928, Vol. 20, June 16, pp. 357–361). A theoretical consideration of the coal-washing process; the subject is dealt with mathematically.

Cleaning Bituminous Coal. J. R. Campbell. (American Institute of Mining and Metallurgical Engineers, 1928, Technical Publication No. 117). A considerable portion of the paper is devoted to detailed results of a series of studies on the washability of bituminous coal. This is followed by a discussion of the methods of coal washing, all the different methods in use in America being dealt with. Methods of drying, sludge recovery, water clarification, washing efficiencies, the cost of washing, and effect of washing, are also dealt with.

Application of Cinematography to the Study of the Fall of Coal Particles in Still Water. W. A. Gooskov. (American Institute of Mining and Metallurgical Engineers, 1928, Technical Paper No. 18). The results are given of an investigation in which photography and cinematography were used to study the velocity of coal particles settling in still water. The importance of this method for investigating coal washing problems is pointed out.

Recent Progress in the Technique of Coal Washing. C. Berthelot. (Revue de l'Industrie Minérale, 1928, May 15, pp. 203–227). The continuation of a series of articles (*see* Journ. I. and S.I., 1928, No. I. p. 742). In this instalment the author deals with the washing of dusts and slimes by various means, the adaptation of existing washers for this purpose, and problems connected with the draining and drying of these materials. The technical and financial aspects of the matter are also given attention, and a section is devoted to the question of decanting and clarifying the wash waters.

The Washing of Coals. A. Moreau. (Revue de l'Industrie Minérale, 1928, No. 184, Aug. 15, pp. 335–340; No. 185, Sept. 1, pp. 349–358; No. 186, Sept. 15, pp. 373–380). An analytical and graphical study of the beneficiation of run-of-mine coal. The author first examines the washability of any particular coal. He then discusses whether, in the case of coals which are to be mixed together, the washing should be done before or after mixing. The question of the optimum degree

of washing which is commercially practicable is also considered. The whole subject is treated mathematically.

The Control of Coal Cleaning Operations. A. N. H. Slade. (Colliery Engineering, 1928, Vol. 5, June, pp. 225–228). The subject is discussed under the following headings : Choice of the specific gravity for float and sink control tests ; control test sampling ; method of testing washery products ; explanation of specimen report sheet ; the application of washability curves to washery control ; and the supervision and personnel of a washery.

The Choice of Washing Systems for Difficultly Washed Coals with Particular Reference to the Preparation of Fine Coals. J. Holik. (Montanistische Rundschau, 1928, Vol. 20, Aug. 1, pp. 461–472).

The Preparation of Coal for the Market. A. Grounds. (Fuel Economist, 1928, Vol. 3, May, pp. 525–527 ; June, pp. 593–597 ; Sept., pp. 773–776). A brief discussion of the tests employed to determine the washability of coal.

The Plant for Removing Clay from the Coal at the Prosper II. Mine, in the Ruhr. C. Berthelot. (Génie Civil, 1928, Vol. 92, June 23, p. 621). The author illustrates and describes briefly the apparatus used for removing clay from fine coals. The principle involves the use of water containing slimes from the washery. In removing the coarse suspension from the dirty water, the clay from the fine coal is simultaneously extracted ; the de-slimed water is ready to be used in further washing operations, and the fine coal free from clay is sent forward to the washery proper.

Coal Washing at the Linsi Mine, Kailan Mining Administration, North China. A. Docquier, L. Bataille, and R. Beetlestone. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 2, pp. 406–444). The plant described is a combination of the Baum, Draper, and froth flotation systems. Operating results are given

Coal Washery at Tynemount Colliery. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, p. 611). A short account is given of the coal washing plant at the Tynemount Colliery, Ormiston. It is of the Blantyre-Baum type, and is arranged to deal with 60 tons of small coal per hour from 3 in. to 0.

New Coal Cleaning Plant at the Heinrich Gustav Colliery, Westphalia. (Iron and Coal Trades Review, 1928, Vol. 117, Nov. 2, pp. 650–651).

A New Anthracite Cleaning Plant. (Colliery Engineering, 1928, Vol. 5, May, pp. 185–194). An illustrated account is given of the screening and washing plants and the refuse disposal ropeway recently erected at the Raven Colliery, South Wales.

The Dewatering and Drying of Coal. R. A. Mott. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, pp. 451–452).

The Drying of Coal. F. Brauneis. (Montanistische Rundschau, 1928, Vol. 20, July 16, pp. 430–433).

Air-Drying of Canadian Lignite and the Reabsorption of Moisture by the Same. J. H. H. Nicolls. (Canada, Department of Mines, Mines Branch, Investigations of Fuels and Fuel Testing, 1926, pp. 51–59). The results are reported of a series of experiments carried out principally to investigate the behaviour of dried lignites when exposed to the same atmosphere as lignites in the process of air-drying. A table is given showing the alterations of moisture content in ground coal samples standing in the laboratory during twenty months under varying conditions of humidity. The figures in the table show that the coals lose moisture as the room humidity falls and reabsorb it with increasing humidity. The figures point to the inadvisability of delaying the analysis of ground coals, particularly in the winter.

The Universal Coal Drier. (Iron and Coal Trades Review, 1928, Vol. 116, June 29, p. 973). **Cascading Coal Drier.** (Engineering, 1928, Vol. 126, July 6, pp. 12–13). The coal drier described is in operation at the Barrow Collieries, near Barnsley. The machine consists essentially of a series of superimposed rotating troughs. The wet coal from the washery is fed into a hopper at the top of the machine, from which it is discharged by means of a rotating distributor into the uppermost trough. This latter tips the coal into the second, and the fuel continues to travel from trough to trough until it is finally discharged at the lower end of the machine. During its downward path, the coal meets an upward current of hot gases drawn through the apparatus by means of a fan. The heating medium may be either coke-oven, producer, blast-furnace, or any waste gases.

Centrifugal Drying of Fine Coal in Belgium and France. J. Steinmetzer. (Glückauf, 1928, Vol. 64, Aug. 18, pp. 1127–1130). The coal drying centrifuge of Hoyle is described, and working results obtained in Belgium and France are reported.

The Sizing of Coal for Briquetting. J. R. Homer. (Paper read before the Institution of Mining Engineers, Oct. 24, 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, pp. 623–624). The author

presents the results of an investigation of briquettes produced from coal of varying sizes. There is not a great disparity between the results obtained with practically all coal passing through $\frac{1}{8}$-in. mesh and those obtained when 20 to 25 per cent. of $\frac{1}{4}$- to $\frac{1}{8}$-in. coal is present. For economic and practical purposes it is desirable to have such a percentage of $\frac{1}{4}$- to $\frac{1}{8}$-in. coal present, while the grading of the " fines " should approximate 50 per cent. of $\frac{1}{32}$ to $\frac{1}{64}$ in. and 50 per cent. of coal from $\frac{1}{64}$ in. downwards. Using 8 per cent. of pitch, with a fairly even grading of the $\frac{1}{4}$- to $\frac{1}{32}$-in. particles, 30 to 40 per cent. of coal from $\frac{1}{32}$ in. downwards should be present for the strongest and most resistant briquettes. While with 10 per cent. of pitch there is a sufficient binder present to give satisfactory results over a wide range of sieve analyses, the best results were usually obtained with the same grading as gave the best for 8 per cent. Briquetting with no " fines " is not to be recommended owing to the rough surface, high porosity, and low density which result. For some purposes, however, a coarse mixture might with advantage be used.

The Manufacture of Combustible Agglomerates [Briquettes]. Agglomeration by Heating. H. Dupuy. (Chaleur et Industrie, 1928, Vol. 9, June, pp. 292–293).

Pulverised Coal. G. E. Allin. (Fuel Economy Review, 1928, Vol. 7, pp. 46–47). A short article comparing American and English practice.

The Application of Pulverised Coal to Industrial Furnaces. W. A. Shoudy. (Iron and Steel Engineer, 1928, Vol. 5, May, pp. 189–198).

Pulverised Fuel Practice on the Continent. (Fuel Economist, 1928, Vol. 4, Oct., pp. 33–38).

Pulverised Fuel Developments in the United States. L. M. Jockel. (Electrical Review, 1928, Vol. 102, June 8, pp. 1013–1014).

Practice and Progress in Combustion of Coal as Applied to Steam Generation. F. H. Rosencrants. (Paper read before the Institution of Electrical Engineers, May 3, 1928 : Fuel, 1928, Vol. 7, June, pp. 272–281). A review of past development, present position, and trend of progress of pulverised fuel firing and stoker firing.

Cupola Fired with Powdered Coal. F. Meyer. (Iron Age, 1928, Vol. 121, June 7, pp. 1593–1595). At the plant of the American Radiator Co., Springville, Illinois, powdered coal is used for the firing of cupolas in conjunction with a minimum coke charge. The coal is burned under pressure in chambers outside the stack, and the hot gases alone are blown into the melting zone. The ratio between the amount

of air for combustion and the amount of powdered coal is so regulated that the atmosphere in the melting zone can be either mildly reducing or neutral. Due to this fact, the coke bed does not get burned out so rapidly as in the ordinary cupola, and it is possible to work with a charge of coke of not more than 2 to 4 per cent. of the iron melted. It is claimed that with this method a better control of the carbon content is secured and the iron produced has better strength properties.

Powdered Coal in Steel Furnaces. E. L. Herndon. (Paper read before the American Society of Mechanical Engineers : Iron Age, 1928, Vol. 121, June 7, pp. 1603–1604). The author describes the use of pulverised coal in basic open-hearth furnaces at the plant of the Eastern Steel Co., Pottsville, Pa. The melting department consists of four 50-ton furnaces and two 80-ton furnaces, all of the stationary type. When pulverised coal was first used it was found that the checkers filled up with ash, and therefore arches were substituted to give greater space. The furnaces are reversed by two dampers, one placed in each flue between the checker chamber and the stack, which gives the products of combustion a direct path to the stack. Each furnace is supplied with two storage bins for the pulverised coal, which have a capacity sufficient to operate a 50-ton furnace for 18 hr. and an 80-ton furnace for 15 hr. The coal is supplied to the furnace by means of compressed air syphons, the air pressure used being 80 lb. per sq. in. Each furnace is equipped with oil burners in case of emergency. The operation of the furnace does not present more difficulty than that of producer-gas fired furnaces. An all-cold charge is used, and the time for charging is about 4 hr. The life of the furnace is about 200 heats for one roof.

Pulverised Fuel Plant for the Use of Colliery Waste. (Engineering, 1928, Vol. 126, Oct. 26, pp. 522–524). **Powdered Fuel at a Colliery.** (Engineer, 1928, Vol. 146, Oct. 26, pp. 466–467). **Pulverised Fuel Plant at Cadeby Main Colliery.** (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 19, pp. 572–573). A detailed illustrated account is given of the pulverised fuel plant at the Cadeby Colliery at Conisborough for the utilisation of coal refuse. The previous boiler plant consisted of 21 Lancashire boilers, of which 13 were removed to make room for the new plant, which consists of 3 water-tube boilers and accessories, with the necessary pulverised fuel plant and fuel and ash conveyors. The new boilers, which are exclusively used for the winding engines, are of the 5-drum type. The working pressure is 125 lb. per sq. in. Fine coal obtained from the screening plant is delivered to storage silos. From each silo the coal descends through discharge gates into an automatic weighing machine and thence flows down to the Holbeck pulveriser. The pulverised fuel storage bin is situated between the storage silos, and has a capacity of 70 tons. The lower part of the bin tapers down from a cylinder to a narrow rectangular

portion coupled to the boxes containing the feed worms, which push forward a definite quantity of coal according to the rate at which the boilers are being fired. The coal is then caught up into a stream of air from the primary air-fans and is discharged through the burner. The coal from the screening plant has a calorific value of 10,600 thermal units, an ash content of 23 per cent., and about $3 \cdot 9$ per cent. of moisture. It ranges in size from $\frac{1}{8}$-in. mesh down to fine dust.

Pulverised Fuel Plant at Whitehaven Colliery. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, p. 614). Particulars are given of the pulverised fuel plant for the utilisation of low-grade fuel in boilers, together with some operating results.

The Centripact Pulveriser. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 651–652). The machine consists of three discs mounted on a common vertical spindle, the top disc being of small diameter and the bottom disc being the largest. On each disc are mounted a number of chilled manganese steel hammers, which are bolted into recessed slots. Opposite each row of hammers is a circular breaking ring, the inner surface of which is corrugated. The material is fed in at the centre at the top, and is both thrown against the breaker rings and pounded by the hammers ; it is discharged at the bottom. The machine has pulverised damp bituminous coal to 90 per cent. through 300-mesh, hard flint rock from $1\frac{1}{2}$ in. down to 85 per cent. through 200-mesh, and has been used for such other materials as mica, damp clay, cast-iron chips, iron ores, &c. A high tonnage at low cost is claimed for the machine.

PEAT.

Peat. G. Kimpflin. (Revue Générale des Sciences, 1928, Vol. 39, July 15, pp. 399–403). The author discusses the constitution of peat and the possibilities of its employment in industry. The two great objections to the use of peat as a fuel are its high water content and its low calorific power. The author describes briefly the manner of reducing the water content, and then deals a little more fully with the granulation of peat, by which process it then becomes suitable for use in a gas-producer. The results are recorded of tests in which peat was fed into a gas-producer constructed to use wood, the gas from which was used to drive a motor designed to run on poor gas.

COKE.

A Review of Coke-Oven Technology during the Year 1927. G. E. Foxwell. (Fuel Economy Review, 1928, Vol. 7, pp. 15–29).

The Development of the Metallurgical Coke Industry in the Ruhr District (Germany). C. Berthelot. (Génie Civil, 1928, Vol. 93, Aug. 18, pp. 153–158 ; Aug. 25, pp. 180–183). The author discusses the following five questions in relation to the industry of the Ruhr region : (1) cost of the coal ; (2) situation and evolution of the metallurgical coke industry ; (3) recovery and use of ammonia in coke-oven plants ; (4) production and utilisation of benzol ; (5) probable uses for coke-oven gas. To exemplify his remarks, the author describes the coke-oven plant at the Sachsen Mine at Hamm, belonging to the Mansfeld Group, and the coke-oven plant at Bruchstrasse, near Dortmund, belonging to the Vereinigte Stahlwerke.

Economics of Coke Manufacture in the Coking Industry. M. Mackenzie. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, pp. 455–456 ; Gas World, 1928, Vol. 89, Oct. 6 (Coking Section), pp. 13–15 ; Gas Journal, 1928, Vol. 184, Oct. 3, pp. 45–48).

The By-Product Coke-Oven as a Source of Industrial and Domestic Energy. C. P. Finn and R. Ray. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas World, 1928, Vol. 89, Oct. 6 (Coking Section), pp. 16–18 ; Gas Journal, 1928, Vol. 183, Sept. 26, pp. 664–666).

New Coking Installation of the South Yorkshire Chemical Works, Ltd. (Iron and Coal Trades Review, 1928, Vol. 116, May 25, pp. 785–787). **A Modern Coke-Oven Plant.** (Engineer, 1928, Vol. 146, Aug. 17, pp. 169–172 ; Aug. 24, pp. 191–195, 202). An illustrated account is given of the layout and equipment of the new battery of 60 ovens erected at this plant. The ovens are of the standard Semet-Solvay double-pass type. Each oven has a mean width of 18 in. and is 11 ft. 7 in. high, the coal capacity being about 13 tons (wet) per charge. On the pusher side the door extractors are mounted on the coke ramming machines. On the coke side there are two combined door extractors and coke guides. The quenching station is placed at the end of the battery. The plant is equipped with recovery apparatus for tar, sulphate of ammonia, and crude benzol.

Colliery Managers' Visit to Germany. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 5, pp. 485–488 ; Oct. 12, pp. 536–540). An account is given of the various coke-oven plants and collieries visited by the National Association of Colliery Managers on their recent visit to Germany. Illustrated particulars are given of the following plants : Kogag coke-oven plant at Emil Pit ; coke-oven plant at Gneisenau Colliery ; collieries of the Gutehoffnungshütte and the collieries of Messrs. Krupp.

The New Coke-Oven Plant of the Lothringen Mining Company at Hiltrop. H. Tramm. (Stahl und Eisen, 1928, Vol. 48, June 7, pp. 753–761 ; Glückauf, 1928, Vol. 64, June 2, pp. 719–729). **A New Coking Plant of the Lothringen Company.** (Colliery Guardian, 1928, Vol. 137, Aug. 10, pp. 536–537). **A New Cokery at Hiltrop.** (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 10, pp. 192–195). The battery consists of 60 ovens, 54 of which are ordinary Koppers ovens, the other six being built on the circulating principle. The ascending gas and air current in one flue draws by suction from the neighbouring flue the descending burnt gases, by which the flame in the ascending flue is lengthened and distributed evenly up the full height of the oven. On starting the oven the burners in flues 1, 3, 5, 7, &c., are in action while the burnt gases are descending in flues 2, 4, 6, 8, &c., and passing to the regenerator ; near the bottom of each flue are small holes through which a proportion of these burnt gases is sucked into the adjacent flue. The whole design is illustrated. The coking time of the whole battery is 11·5 hr.—that is, every oven is pushed twice in 24 hr., and the total daily throughput is 1000 tons. A novel feature is that the coal before charging is dried in a rotary tubular drum heated by waste gas. The coke is dry-cooled as a rule, and the heat is utilised for steam raising by circulating the gases through a system of pipes. For emergency a wet quenching plant is installed. Various new improvements have also been introduced into the by-product recovery plant.

New Coking Plant Developments in Germany. (Fuel Economist, 1928, Vol. 4, Oct., pp. 54–56). Much attention has been paid to the problem of increasing the throughput of the ovens. Technical improvements in coke-oven construction are of many kinds, not all of which are generally considered to be advantageous. Shortening of the coking period and the avoidance of over-coking is obtained through the employment of relatively narrow chambers tapering towards the top, and through the introduction of a number of combustion points in the heating space, to ensure that all parts of the coke charge be simultaneously and uniformly heated. Through improvements in the method of heating the charge it is possible to use much larger ovens than formerly. The coking plants of the " Nordstern " have ovens with a vertical height of 6 m., a length of 12·4 m., and a breadth of chamber of 0·45 m. The capacity is about 32 cu. m. and the charge 28 to 29 tons of wet coal. With a coking period of 18 hr. the daily output of coke per oven is 36 tons. Further progress in coking technique is indicated by the practice at the coking plant of the Lothringen concern of pre-drying the coal in a rotary drying furnace. The practice of charging dry coal is said to favour a long life for the coke-oven walls.

New Coking Plant of the Vereinigte Stahlwerke Co., Ltd., Hörder Verein Subsidiary Co., Hörde. F. Winklhöfer. (Stahl und Eisen, 1928,

Vol. 48, May 24, pp. 689-693). The works are described and illustrated. Special attention has been paid to the mechanisation of the plant by the use of band conveyors, overhead conveyors, &c.

Manufacture of Coke at Masillon. C. R. Lohrey. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Aug., pp. 1063–1069, 1075). A description of the general layout and operation of the Masillon coke plant of the Central Alloy Steel Corporation.

New Plant of Montreal Coke and Manufacturing Company. D. G. Munroe. (Iron and Steel of Canada, 1928, Vol. 11, Aug., pp. 228–230). Some notes are given of the coal and coke handling plant, coke-ovens, and by-products plant of this company.

An Examination of the Influence of Various Factors on the Products of the Carbonisation of Coal. H. H. Thomas. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Mar. 23, pp. 77–83T).

Some Aspects of the Process of Coal Carbonisation. E. V. Evans. (Lecture to the North British Association of Gas Managers : Gas World, 1928, Vol. 89, Sept. 8, pp. 205–209).

The Manufacture of Coke-Oven Gas. G. E. Foxwell. (Colliery Engineering, 1928, Vol. 5, Oct., pp. 407–410 ; Nov., pp. 448–453). The subject is discussed under the following headings : Influence of the character of the coal upon the quality and quantity of the gas ; influence of the conditions under which the coal is carbonised ; effect of the temperature to which the gas has been exposed ; influence of the pressure conditions in the hydraulic main ; fuel consumption for heating ovens ; influence of the width of oven on the yield of surplus gas ; effect of silica construction and high heats ; uneven heating of the oven wall ; the use of dry coal ; the design of the regenerators ; influence of the character of the coal upon heat consumption for carbonisation ; and the manufacture of coke-oven gas to a standard specification.

The Influence of Air Velocity on Uniformity of Temperature in Coke-Oven Flues. J. W. Cuthbertson. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 17, pp. 228-229). The author has made investigations of a flue built to represent on a small scale those used by the Simon-Carvés Co. in the construction of their ovens. The chief arrangement of the experimental flue is shown and the method of conducting the investigation is described. It is concluded that when using one gas and one air port the best temperature distribution is obtained when using approximately equal low gas and air velocities, the air being pre-heated to as high a degree as possible. With low velocities, up to about 12 ft. per sec., the ports must be placed near together. If this is not done combustion is imperfect. The gas and

air travelling upwards in two parallel streams are only in contact on two sides, and when the velocities are low, the rate of diffusion of the one stream through the other is not sufficiently rapid, during the upward flow of the gases, to bring about a thorough mixing and consequent complete combustion. For this reason a larger amount of excess air is required. This is very detrimental; the excess air causes a lowering of the maximum temperature of the flue by reason of its temperature being below that of the flue, and there is a loss of heat from the flue-stack gases owing to their volume being increased by the inert additional air. The ideal arrangement would be to have one gas port of circular section placed in the centre of the flue base and to place two rectangular air ports at equal distances from and on opposite sides of the gas port. By utilising this construction the gas stream would be supplied by air on two opposite sides, and the mixing of gas and air would be thorough but not too rapid.

The Effect of Pre-Oxidation on the Primary Distillation Products of Coal. Part I.—The Preliminary Oxidation of Coal. J. T. Donnelly, C. H. Foott, H. Nielsen, and J. Reilly. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Jan. 13, pp. 1–4T). **Part II.—The Controlled Preliminary Oxidation of Coal.** (May 18, pp. 139–142T). **Part III.—The Effect of Carbon Dioxide, Carbon Monoxide, Hydrogen, and Nitrogen on Coal at Temperatures up to 200°.** (May 18, pp. 142–143T). **Part IV.—The Distillation at 600° of the Oxidised Coal Samples.** (July 13, pp. 189–192T).

The Properties of Coking Coals and the Reactions during their Coking. P. Damm. (Glückauf, 1928, Vol. 64, Aug. 11, pp. 1073–1080; Aug. 18, pp. 1105–1111). In the coking of coals two properties are of particular importance : (1) the caking capacity, and (2) the ability to swell; by simple processes, numerical values may be determined for these. The figures for the caking capacity give indications of the melting properties of the coals, while the pressure exerted during swelling shows the pressures applied to the coals in the plastic state by the liberated gases of decomposition. A further insight into the coking process is obtained by a determination of the course of the liberation of the gases, which occurs in three stages. The preliminary liberation of gases below the softening point of the coal gives information concerning the changes which the coal suffers in greater or less degree on being heated up to its softening temperature. The gases evolved within the softening range provide evidence concerning the ability of the coal to swell ; while the final evolution of gas—as also the loss of substance of the already re-solidified coal mass—is of importance for the determination of the quality of the resulting coke. Finally, it is shown what influence those properties of the coal which are of importance in the coking process have on the quality of the coke produced, and how these properties influence the process of coking itself.

1928—ii. T

Investigations into the Reactions of the Coking of Coals. G. Agde. (Glückauf, 1928, Vol. 64, Sept. 22, pp. 1288–1290). A discussion of the reactions occurring during the coking of coal. The author is in agreement with the findings of Damm (*see* preceding article).

Comprehensive Account of Previous Investigations into the Heats of Decomposition and of Coking of Coals. H. Hock and H. Stuhlmann. (Glückauf, 1928, Vol. 64, Oct. 27, pp. 1445–1451). The methods proposed by various investigators for determining the heats of decomposition and of coking of coals are reviewed ; a critical consideration shows that in some directions considerable differences are to be found among the results obtained, and it is only in recent times that the work has been carried out with sufficient accuracy. The factors entering into the preparation of a coke-oven heat balance are discussed, and the importance and influence of the heats of decomposition and of coking in relation to such a heat balance are pointed out.

A Further Study of Coke Formation. R. A. Mott and T. Shimmura. (Fuel in Science and Practice, 1928, Vol. 7, Nov., pp. 472–486). In an earlier paper (*see* Journ. I. and S.I., 1927, No. II. p. 497) the formation of coke was studied for a series of lump and crushed coals at a specified rate of heating. In the present research a number of moderate and inferior coking coals have been subjected to similar methods of examination, the effect of rate of heating has been studied, and an investigation of the cause of swelling has been begun. The coals examined were from nine seams ; four from a Yorkshire colliery and five from a Derbyshire colliery. All the experiments made so far confirm the observation that the swelling power of coals varies directly with their carbon contents, being greatest for coals of high carbon content (up to a limit of 90 per cent. carbon) and least for coals of low carbon content. The swelling power of coals is also directly related to their coking power. Swelling is not due to rate of gas evolution *per se* but is primarily dependent on the tar produced. It seems likely that it is not only the amount of tar produced over a critical temperature range which is important, but also the ease with which the rest of the coal is wetted by the tar. A large quantity of tar might be available at the coal surfaces and in the interstices between the particles, but this could be easily displaced from the coal surfaces if the adhesion (wetting) were poor—as appears to be the case with coals of high oxygen content. Support is given to the suggestion that the first stage of coke formation from crushed coal is the liquation of oil (tar) to the surfaces of the coal particles until the surfaces are completely wetted ; the cohesion of the oil films round different particles causes a preliminary binding of the coal particles into a " cake." The second stage of coke formation from crushed coals is the loss of identity of the coal particles with the formation of pore structure due to swelling.

The Influence of Inorganic Constituents in the Carbonisation and Gasification of Coal. The Liberation of Sulphur. J. J. Priestley and J. W. Cobb. (Gas Journal, 1928, Vol. 182, June 20, pp. 951–954). This paper forms Part II. of the Gas Research Fellowship Report for 1928. The authors have carried out experiments in which coal was carbonised in nitrogen or hydrogen at temperatures of 100° up to 1000° C., maintaining the temperature for an hour at each stage and 12½ hr. altogether. They also investigated the influence of inorganic constituents on the liberation of sulphuretted hydrogen. The results are presented in tables and figures, and the amounts of sulphuretted hydrogen liberated at each stage of each temperature and up to each temperature in both nitrogen and hydrogen are expressed as percentages of the total sulphur of the coal and plotted for the several mixtures.

The Use of Graphical Methods in the Control of a Coke-Oven Plant. G. W. J. Bradley. (Fuel, 1928, Vol. 7, June, pp. 258–267). The author illustrates how graphical methods can be applied to (a) the control of a crude benzol plant; (b) cost estimation; (c) the calibration of horizontal cylindrical storage tanks.

Studies in Carbonisation. Part III.—**Temperature, Size of Coal, Blending with Coke and Inorganic Compounds.** (Gas World, 1928, Vol. 88, June 16, pp. 633–635; Gas Journal, 1928, Vol. 182, June 20, pp. 883–888). The work described in this report constitutes the 20th Report of the Research Sub-Committee of the Gas Investigation Committee of the Institution of Gas Engineers. The whole of the experiments have been conducted with a Nottinghamshire gas coal of moderate coking properties. Although the total volumes of gas made at given temperatures, when carbonisation had been completed, were generally independent of the size-grading of the coal, the rates at which gas was evolved as the carbonisation proceeded varied considerably. In the earlier stages of carbonisation, gas was evolved most rapidly from the largest grade of coal, and the rate of gas production decreased with diminution in the size of coal. With mixtures of sizes, the rates of gas production were not very different from those obtained with the smallest grade, 8 to 30 mesh, carbonised alone. Considerable economies might, therefore, result from the screening of coal for gas production, the screened coal and the fines being carbonised separately. The time required for satisfactory carbonisation of each charge of 30 lb. of coal increased rapidly as the temperature of the retort was lowered, from 2½ hr. at 915° C. to 10 hr. at 630° C., and 20 hr. at 525° C. The time factor is of importance, especially when considering low-temperature carbonisation with externally heated retorts and static charges; the appreciation of this factor has resulted in a number of inventions. To ascertain whether the addition of coke breeze to the 8 to 30 mesh coal influenced the carbonisation process, mixtures containing 10 per cent. and 20 per cent. by weight of coke were carbonised

with the retort at 920° C. and 815° C., and the 10 per cent. mixture was also carbonised at 725° C. and 630° C. The addition of coke breeze had no marked effect on the composition and calorific value of the gas made, and the yields of gas and tar expressed in amounts per ton of coal were not greatly altered. Larger quantities of ammonia were obtained in all tests with coal-coke mixtures than with coal alone. The addition of inorganic compounds resulted in larger proportions of ash in the coke made, and iron oxide caused increases in the percentage of sulphur.

The Fundamentals of Coal Blending and the Production of Solid Smokeless Domestic Fuel. J. G. King. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas Journal, 1928, Vol. 183, Sept. 26, pp. 668–670).

Coke Quenching and Cooling. W. Colquhoun. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas Journal, 1928, Vol. 183, Sept. 26, pp. 657–658).

Dry Quenching of Coke. W. Sennhauser. (Iron and Steel Engineer, 1928, Vol. 5, May, pp. 184–189). The advantages of the Sulzer system of dry quenching coke are enumerated.

Dry Coke Cooling by the Collin System. E. Arnold. (Stahl und Eisen, 1928, Vol. 48, July 5, pp. 903–907). At the Henrichshütte at Hattingen in the Ruhr a dry coke cooling plant on the Collin system was installed in 1927. The chief reason for its adoption was the very large steam requirements in the works, and it was found economical to utilise the heat of the coke for auxiliary steam raising. Two batteries of 50 ovens each were planned in 1921. Of these one battery was built and equipped for wet quenching, and the other 50 ovens have now been erected and dry quenching has been adopted. It is reckoned that the additional cost of the dry cooling equipment will be saved in two years. Ten per cent. has been added to the total quantity of waste heat previously utilised, the cost of production of the coke is reduced by 1s. per ton, and the ash content is reduced by more than half. An illustrated description of the technical details is given. One cooling chamber is built in front of every three ovens, into which the coke is discharged. At the bottom of every cooling chamber is a stepped grid through which a cold mixture of gas is passed, which is drawn off through the top of the chamber after passing through the incandescent coke, and is circulated through the superheater, tubes, and feed-water heater of a boiler. The gas is by that time cooled down to 70° C., and is pumped back to be passed again through the coke cooling chamber. Its temperature on reaching the superheater is 500° to 600° C. Superheated steam at 350° C. is generated at a pressure of about 200 lb. per sq. in., and 5 to 6 tons of water per hour

are evaporated. No evidence has yet been obtained as to whether there is any loss of coke by burning.

Coke Screening. W. S. Edwards. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas Journal, 1928, Vol. 183, Sept. 26, pp. 658–659).

Some Technical and Economic Aspects of the By-Product Ammonia Recovery Problem. P. Parrish. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas World, 1928, Vol. 89, Oct. 13, pp. 339-343 ; Gas Journal, 1928, Vol. 183, Sept. 26, pp. 677–679).

The Utilisation of Coal. O. Huppert. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, July 14, pp. 975–983). The author discusses the various ways in which the maximum utilisation is made of the coal, such as the synthesis of ammonia, the manufacture of nitrogen salts, distillation, the production of hydrogen by the Bronn-Linde-Concordia process and of primary tar by the Prudhomme process, the production of liquid fuels by means of carbon monoxide, &c. He further discusses the hydrogenation of coal and tar, and the production of water-gas from coke-oven gas.

On Distillation Tar from Köflach Steam-Dried Coal. F. Neuwirth. (Berg- und Hüttenmännisches Jahrbuch, 1928, Vol. 76, Oct. 1, pp. 75-80). An investigation into the nature of the compounds existing in the tar obtained by the careful distillation of coal from Köflach, dried by steam under pressure, is described.

Low-Temperature Carbonisation. C. H. Lander. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 5, pp. 499-501).

Low-Temperature Carbonisation. R. A. Strong. (Canada, Department of Mines, Mines Branch. Investigations of Fuels and Fuel Testing, 1926, pp. 11-35). The results are reported of low-temperature carbonisation tests on ten Canadian bituminous coals. In respect of yield and quality of the low-temperature coke obtainable all the coals showed favourable results. With one exception, however, the coals tested were not specially suitable for low-temperature carbonisation on account of the comparatively low tar oil and gas yields.

Kinneil Gas Coal—Its Carbonisation. (Fuel Research Board, Physical and Chemical Survey of the National Coal Resources, Report No. 11 ; Iron and Coal Trades Review, 1928, Vol. 117, Aug. 3, p. 164). The Report contains the results of tests on the carbonisation at high

temperatures of Kinneil gas coal in continuous and vertical retorts. The coal was also subjected to low-temperature carbonisation in a setting of retorts designed at H.M. Fuel Research Station, and the various cokes were tested for steam-raising purposes in a Lancashire boiler and for fuel gas production in three types of gas plant.

Low-Temperature Carbonisation of Lignites and Sub-Bituminous Coals. J. D. Davis and A. E. Galloway. (Industrial and Engineering Chemistry, 1928, Vol. 20, June, pp. 612–617). Comparative low-temperature assay tests were made on 24 sub-bituminous coals and lignites by three different methods : (1) The oil-shale method, developed by the Bureau of Mines ; (2) the Gray and King method, developed in England ; and (3) the Franz Fischer method as used in Germany. The results, which are given in tabular form, give a general idea of the yield of products to be expected from coals of this rank. The authors find that the Franz Fischer method gives the most concordant results.

Low-Temperature Carbonisation. D. Brownlie. (Iron and Coal Trades Review, 1928, Vol. 116, June 22, pp. 940–941). The author summarises the outstanding features of the following processes : Bartling, Bussey, Dvorkovitz, Hanl, Hönigmann-Bartling, Plassmann, Salerni, Sauerbrey, Shimomura, Trent Super Fuel, Trumble, and Winser.

The Production of Smokeless Domestic Fuel. J. Roberts. (Gas Journal, 1928, Vol. 183, July 4, pp. 42–43 ; July 11, pp. 87–88 ; July 18, pp. 153–154 ; July 25, pp. 211–212 ; Aug. 1, p. 265 ; Aug. 8, pp. 310–311 ; Aug. 15, pp. 356–357). Particulars are given of the following processes : Illingworth, Parr and Layng, Wisner or Carbocite, Heller-Bamag, Sutcliffe, Midland Coal Products, Maclaurin, L and N, Turner, Hird, Coalite, and Homite (Roberts).

Low-Temperature Carbonisation of Bituminous Fuels. F. H. Martin. (Revue de l'Industrie Minérale, 1928, No. 185, Sept. 1, pp. 359–364). A description is given of the new type of mechanical retort constructed by the Société des Mines de l'Estérel, Fréjus, in 1925 for distilling the rich but sticky schists obtained from the Boson district. The installation at Boson consists of six retort units grouped in pairs. The raw material, of which the analysis is given, is charged mechanically into hoppers above the retorts, and discharging is also effected by means of a conveyor. Each unit consists of a retort proper of cast steel, and of a masonry structure comprising a Siemens producer, a recuperator, and a combustion chamber surrounding the retort. The retort is formed of two " twinned " horizontal cylinders ; propelling and mixing gear inside them brings every particle of material into contact with the hot walls and prevents it from sticking. The capacity of a retort is from 10 to 12 cu. m. per 24 hr., the time of

distillation being about 2 hr. The temperature varies between 470°
and 500° C., being regulated to within 10° C. by adjusting the rate of
feed. The results quoted show a high efficiency.

Low-Temperature Carbonisation. (Gas Journal, 1928, Vol. 183,
Aug. 22, pp. 412–413). Particulars are given of the results obtained
with the K.S.G. low-temperature carbonisation plant at the Karnap
Works of Mathias Stinnes.

The Illingworth Process of Low-Temperature Carbonisation. (Colliery
Guardian, 1928, Vol. 137, Sept. 7, pp. 919–923 ; Iron and Coal Trades
Review, 1928, Vol. 117, Sept. 7, pp. 323–325). An illustrated account
is given of the Illingworth process, including results of operating tests.

Low-Temperature Carbonisation. D. Muir. (Paper read before
the Wales and Monmouthshire District Institution of Gas Engineers
and Managers, Sept. 27, 1928 : Gas Journal, 1928, Vol. 184, Oct. 3,
pp. 30–34). An account is given of the Illingworth carbonisation
plant in operation at the Treforest Gasworks.

Low Temperature Carbonisation at Dunston. (Colliery Engineering,
1928, Vol. 5, Nov., pp. 428–432, 456). **The " Babcock " Low-Tempera-
ture Coal Distillation System.** (Gas Journal, 1928, Vol. 184, Nov. 14,
p. 469). An illustrated description is given of the plant erected by
the Newcastle-on-Tyne Electric Supply Co., Ltd., for the low-tempera-
ture treatment of coal, and the subsequent firing of the coke under
boilers. The boiler-house contains four boilers, four retorts, and
pulverising plant. Northumberland rough slack coal is pulverised
and utilised to fire one of the 30,000-lb. boilers along normal lines. By
regulating the supply of fuel to this boiler, variations in steam demand
can be met, thus permitting the other coke-fired boilers to operate
under steady conditions. A second 30,000-lb. boiler is coke-fired with
fuel derived from two retorts, which have a capacity of 30 tons per
day, while the other two boilers are operated as one unit with a capacity
of 18,000 lb. per hr., utilising fuel from two 20-ton retorts. The heating
of the low-temperature carbonisation retorts is effected by the passage
through the coal of a mixture of hot gases and low-pressure steam,
the latter being supplied as far as possible from the quenching of the
coke on its way to the stoker hoppers. The hot gases are provided
by the combustion of fuel in a firebrick chamber below each retort.
At Dunston coke-oven gas is normally utilised for this purpose, though
arrangements are made for the alternative use of either producer-gas
or pulverised coal.

Low-Temperature Carbonisation. H. P. Hird. (Chemistry and
Industry, 1928, Vol. 47, Jan. 13, pp. 30–32). Particulars are given of
the Hird process of low-temperature carbonisation.

The Pieters Continuous Carbonisation Process. (Engineering, 1928, Vol. 126, Sept. 21, pp. 363–364). The general arrangement of this plant is illustrated and described.

The Karburite Process. F. Brauneis. (Montanistische Rundschau, 1928, Vol. 20, May 1, pp. 253–256). The products of the process and their application, the principles underlying the process, the apparatus required, and the manner of carrying out the process, plant and working costs, the raw materials, and the economics of the process are discussed.

The Lurgi Process. F. A. Oetken and O. Hubmann. (Montanistische Rundschau, 1928, Vol. 20, July 16, pp. 425–430). The Lurgi process for low-temperature carbonisation and its advantages are discussed. The plant employed is described and illustrated. In this process, raw fuel is heated by the passage through it of a stream of heated gas ; it is particularly applicable to young coals such as lignite, cannel coal, &c.

A Chemical Study of Low-Temperature Tar. G. T. Morgan. (Journal of the Society of Chemical Industry, 1928, Vol. 47, May 18, pp. 131–133T). The author describes a preliminary investigation of the original constituents of low-temperature tar. Separation by volatile solvents was substituted for separation by distillation.

The Calorific Value of Metallurgical Coke and of Other Forms of Carbon. W. A. Roth. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 245–247). The author describes the estimation of the calorific values of five samples of different varieties of metallurgical coke by the bomb calorimeter. He gives the results so obtained and also values determined for some of the other varieties of carbon, such as β graphite (carbon from kish, spiegeleisen, blast-furnace sows) and α graphite (temper carbon), and also for some non-graphitic forms of carbon.

Desirable Characteristics of Coke. J. D. Davis. (Paper presented before the American Gas Association, May 23, 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Aug. 24, pp. 262–263).

Microscopic Studies of Graphites and Cokes. P. Ramdohr. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 669–672). In making microscopic investigations of minerals the author noted that it was very easy to detect the presence of graphite, and it occurred to him that the mineralogical microscope might be usefully applied to the study of the theory of coke formation. The preparation of polished sections of coke presents no difficulty if the coke is boiled in a good hard sealing-wax without colouring matter. The optical behaviour of the graphite is quite distinctive, and grains of 1 μ square can be

readily detected. Graphite is so opaque that light does not visibly pass through a flake of over $\frac{1}{2}$ μ thickness, which means that the absorption index has a fairly high value. This method of examination with a mineralogical microscope using polarised light affords a more effective means for the study of coke formation than the X-ray method. Some excellent micrographs illustrate the structure and constituents of coke as revealed by the microscope.

Correlation of Physical and Chemical Properties of Cokes, with their Value in Metallurgical Processes. W. T. K. Braunholtz, G. M. Nave, and H. V. A. Briscoe. (Fuel in Science and Practice, 1928, Vol. 7, Mar., pp. 100–117).

Some Factors Influencing Reactivity of Coke : (*a*) **Carbonising Temperature and Heat Treatment in Nitrogen.** J. A. Sutcliffe and J. W. Cobb. (*b*) **Heat Treatment in Hydrocarbon and Other Gases.** F. J. Dent and J. W. Cobb. (Gas Journal, 1928, Vol. 182, June 20, pp. 946–951). The work described forms Part I. of the Gas Research Fellowship Report for 1928. The experiments lead to the following view : When the charge under carbonisation has reached the desired maximum temperature, and is kept there for some hours, a structure with a corresponding reactivity is impressed upon the coke, and is characteristic of a coke prepared and *held* at that temperature. When a coke has been so prepared, further heat treatment for some hours in a neutral atmosphere such as nitrogen does not materially affect its reactivity, although very prolonged treatment over some days will do so. (This emphasises the importance of the rate of heating through different temperature ranges as a factor in influencing the reactivity of the coke finally made.) If, however, the coke is subjected to the action of hydrocarbon gases, particularly at temperatures from 700° C. upwards, the reactivity of the coke is impaired, even when the amount of decomposition of the hydrocarbons is quite small. If the temperature is high and much deposition of bright " methane " carbon on the coke takes place, the effect is much more marked, and persists very much longer while the carbon is being gasified.

Effect of Physical Characteristics of Coke on Reactivity. J. D. Davis and D. A. Reynolds. (Industrial and Engineering Chemistry, 1928, Vol. 20, June, pp. 617–621). The results of reactivity tests of low and high temperature cokes in air, steam, and carbon dioxide, over temperature ranges from 800° to 1100° C., are given. In general, reactivity varies inversely as bulk density and directly as volatile matter content, but this relation does not always hold, particularly with cokes varying only slightly in reactivity. The effect of volatile-matter content is probably only incidental ; it indicates the temperature conditions under which the coke was made, which are the governing factors. Reactivity varies inversely with the size of test particles, and will in

general vary directly as the adsorptive power. Both properties affect the extent of reactive surface, and hence are interrelated. Size of particles has perhaps the greatest influence on reactivity of high-temperature cokes, because their adsorptive capacity is very low. The reactions here appear to take place almost entirely at the external surface. Different coke particles of the same sample show different reactivities, as is manifested by selective blackening of the more reactive particles during test. The duller portions of the same piece of coke, provided they come from the centre of the coke charge, are much more reactive than the brighter portions—because they have not been subjected to severe heating conditions. Blackened particles found after making the reactivity test came originally from the dullest portions of the coke.

The Reactivity of Coke. F. J. Dent. (Paper read before the Scottish Junior Gas Association : Gas Journal, 1928, Vol. 184, Oct. 17, pp. 199–201).

Moisture in Coke. H. MacPherson, L. Slater, and F. S. Sinnatt. (Fuel in Science and Practice, 1928, Vol. 7, Oct., pp. 444–448). The authors have investigated the relation between temperature of carbonisation and extent of moisture absorption of coke. Specimens of coke were prepared in the laboratory by two methods of carbonisation : (a) in the Lessing carbonising assay furnace, and (b) in the Gray-King carbonising apparatus. One series of experiments was carried out upon four typical Yorkshire coking coals, carbonised at temperatures between 300° and 900° C. Approximately 5 grm. of the residue from each experiment were spread out in a thin layer and dried at 105° C. for 1 hr., weighed, and freely exposed to the atmosphere, dust being excluded. The amount of moisture absorbed by the residue was determined after exposure in this manner for 24, 48, and 96 hr. In each case the normal moisture content was achieved at the end of 24 hr. The greatest amount of moisture would appear to be absorbed by the residues after carbonising at approximately 700° C. ; at 800° C. the amount is somewhat less, falling rapidly as the temperature of carbonisation increases. The results obtained did not confirm the assumption often made that cokes from inferior coking coals absorb the greatest amount of moisture. The gain in moisture is rapid during the first 8 hr., thereafter the increase is less rapid. From the point of view of sampling and analyses the results are of interest, for, if the period of sampling be unduly prolonged, or should the sample, when prepared for analysis, be exposed to the air for a number of hours before the moisture determination is carried out, erroneous results may be obtained.

Coke Tumbler Tests. A. R. Powell and D. W. Gould. (Industrial and Engineering Chemistry, 1928, Vol. 20, July, pp. 725–728). A series

of physical tests of coke have been made in a coke tumbler, following a design suggested by W. A. Haven, and recently suggested for adoption by the American Society for Testing Materials. Duplicate tests in the coke tumbler give results which are concordant within 1·4 per cent. for the stability factor (total per cent. on 1-in. screen) and within 0·8 per cent. for the hardness factor (total per cent. on $\frac{1}{4}$-in. screen), the agreement being closer than duplicate results with the standard shatter test. Comparative results are given for twenty-six different cokes as to shatter test, tumbler test, and how these compare with actual plant yields of coke over 2 in. and coke over 1 in. The stability factor, as determined by the tumbler test, correlates with plant yields of sized coke only in a general way. The tumbler test does not imitate the type of handling which coke receives in the plant so nearly as the shatter test, but it is indicative of the ability of sized coke to withstand handling between the point of production and the point of use. The hardness factor, as determined by the tumbler test, has little practical significance. The effects due to certain variables, such as duration of test, possible sampling errors, and moisture content of coke, have been evaluated.

Improved Process for Testing the Strength of Blast-Furnace Coke. W. Wolf. (Fuel Economist, 1928, Vol. 3, May, pp. 530–532). The concluding instalment of an abridged translation of an article which appeared in Stahl und Eisen, 1928, Vol. 48, Jan. 12, pp. 33–38. (*See* Journ. I. and S.I., 1928, No. I. p. 757.)

GASEOUS FUEL.

Modern Gas-Producers. I. A. Bailey. (Proceedings of the Staffordshire Iron and Steel Institute, 1927–28, Vol. 43, pp. 12–20). Recent types of gas machines are briefly described.

A Pre-Coking Gas-Producer. J. Roberts. (Colliery Engineering, 1928, Vol. 5, May, pp. 207–208). Particulars are given of the Wollaston gas-producer designed to treat coking and swelling coals, particularly fines and dust.

New Fuel Feed for Gas-Producers. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, p. 650). A brief illustrated description of the Wellman double-bell fuel feed. Two " bell and cone " units, one above the other, are operated automatically, so that one is closed while the other is open. They are of special alloy steel and are spherically shaped so as to secure perfect closing. Feeding is regulated by a rotating, fingered vane-wheel. Fuel from slack up to 3-in. size can be fed into the machine.

Full Mechanical Gas-Producer. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1218–1219). Particulars are given of the new mechanical gas-producer known as type SB–10 recently brought out by R. D. Wood & Co., Philadelphia. Operating results obtained with this type of producer are tabulated.

Gasification of Lignite. J. H. Hruska. (Fuels and Furnaces, 1928, Vol. 6, July, pp. 907–908). The results are given of tests on the gasification of lignite in a Kerpely gas-producer.

An Air-Protected Poke-Hole for Producers. R. Bardot. (Génie Civil, 1928, Vol. 92, May 26, pp. 520–521). The Heurtey poke-hole is described; it is intended to prevent the gases within the producer from issuing when the poke-hole is opened up. Surrounding the hole proper is a small hollow annular casting; it is pierced on its inner face by a slit running completely round. Low-pressure compressed air is automatically supplied to the hollow casting when the hole is opened, and the air, suitably directed by the shape of the slit, forms a cone-shaped " curtain " across the hole and prevents the gases from escaping from the producer.

Aspiration Type of Gas-Producer on the Otto System. (Génie Civil, 1928, Vol. 93, Aug. 4, p. 120). The type C of this gas-producer, constructed by the Société des Moteurs à Gaz et d'Industrie Mécanique, is intended to utilise French lean coals and small coke. The feature of this gas-producer is that the air required for its operation is caused to enter into it by the suction of the gas engine to which it is supplying gas. The upper part of the producer is surrounded by an annular space containing water. This " boiler " is heated by the sensible heat of the gases rising from the lower part of the producer, and the steam generated is led down a pipe and introduced into the generator beneath the grate.

Revolving Grate Gas-Producers of the Demag Company. (Génie Civil, 1928, Vol. 93, Oct. 6, pp. 331–332). A gas-producer with a moving grate built by the Demag Company is described and illustrated. A sketch and brief particulars of a producer for gasifying coke waste, fitted with a waste-heat boiler, are also given.

On the Desulphurisation of Gas by Means of Köflach Lignite. F. Neuwirth. (Berg- und Hüttenmannisches Jahrbuch, 1928, Vol. 76, Jan. 15, pp. 1-13). The laboratory experiments described showed that gas could be completely freed from its H_2S and SO_2 contents by the use of raw lignite, particularly at a raised temperature, and that the activity of the absorbent could be regenerated by simple washing with water. The optimum temperature for absorption was 70° to 80° C., though if the gas contained tar it had to be raised

sufficiently to prevent condensation of the tar on the lignite. Half-scale and full-scale tests showed the process to be feasible though troublesome with tarry producer-gas, and the amount of lignite employed was considerable. The desulphurisation of a pre-cooled SO_2-rich chimney gas was easily performed in the half-scale tests. Producer-gas practically free from tar was also successfully treated on a large scale, though the sulphur extraction was only 80 to 90 per cent. complete, due to the small size of the apparatus and the imperfect freedom of the gas from tar. By using more lignite and absolutely tar-free gas as yielded by Theisen washers or electrostatic cleaners the extraction should reach 100 per cent. The process should be applicable directly in gasworks or coke-oven plants, to dispense with the sulphur absorbents now used. The spent lignite could be used under boilers, &c. For open-hearths the gas produced by this process would be suitable, even for high-quality steel, as the complete removal of the sulphur would produce a non-luminous flame. If a dirty gas were used it would be necessary to de-tar it before desulphurising it, to prevent condensation on the lignite ; the tar could be sprayed into it again before use.

The Cleaning of Blast-Furnace Gas. A. J. Boynton. (Paper read before the American Institute of Mining and Metallurgical Engineers, Feb. 1928 : Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 623–628). (*See* Journ. I. and S.I., 1928, No. I. p. 760.)

Notes on Electrical Dust Precipitation. E. H. Lewis. (Journal of the West of Scotland Iron and Steel Institute, Session 1927–28, Vol. 35, pp. 98–100). The arrangement of the Oski plant for treating gases from a cement kiln at Wishaw is shown. The main difference between the Lodge-Cottrell and the Oski types of plant is, first, in the nature of the precipitating electrodes, and, secondly, in the absence of the necessity for rapping the plates. The electrodes in the Oski plant instead of being electrical conductors are only semi-conductors, and consequently there is much less danger of what is called " back ionisation." At Wishaw the quantity of gas treated per hour is approximately 560,000 cu. ft. at normal temperature and pressure. The gas when it comes from the kiln is at about 400° to 500° C. Owing to the nature of the reinforced concrete plates, they are not able to stand up to very high temperatures, and it is desirable to keep the temperature low. The gases are therefore cooled to about 200° C. before they are treated electrically, by sprays of water in the original dust chamber. The quantity of water used is about 9 gal. per minute.

The Electrical Removal of Tar from the Gases from Producers using Lignite. A. Becker. (Braunkohle, 1926, Vol. 25, May 29, pp. 189–195). The Lurgi process of tar removal (Cottrell-Moller patent) has

been installed at the Wolfener Farbenfabrik at Bitterfeld ; it operates at 55,000 v. The gas leaves the producer at 300° C., and on passing through a preliminary cooler and bag-house the temperature drops to 100° C. The gas then passes through the first electric precipitator, which is heat insulated ; in this the insulated electrodes are placed between parallel plates. The tar fog is removed, 77 per cent. of the total tar being deposited, and the gas is said to be cleaned to the first degree. The plant works at a temperature above the dew point of the gas. The gas next circulates through three water washers, where the temperature drops from 85° C. to 25° C. ; oil collects on the water surface. This cooling precipitates a second tar fog, which is collected in a second electrical cleaner which operates in the cold.

Cleaning of Gas. Note on the Electrostatic Cleaning of Tars. M. Stoss. (Journal des Usines à Gaz, 1927, Vol. 51, July 5, pp. 265–267). The electrostatic cleaning of gas is described and the advantages of the process are discussed. It is stated that in France there is only one installation, at the Marseilles gasworks, while in Germany $1\frac{1}{2}$ million cu. m. of gas are cleaned daily, and in America there are some very large plants (that at Philadelphia alone deals with 850,000 cu. m. of gas per day).

The Cleaning of Gases by Electrical Precipitation of the Dust. (Génie Civil, 1928, Vol. 92, June 2, pp. 529–533). The principles of the electrostatic precipitation of dust are discussed and its application to the cleaning of the gases and fumes from works of various kinds is described.

Collection of Industrial Dust. Mechanical and Electrical Processes for the Purification of Gas. E. Lévêque. (Bulletin de la Société d'Encouragement, 1928, Vol. 127, June, pp. 529-541). The author discusses the various processes for separating the dust from gases.

The Clarification of Blast-Furnace Gas-Washer Water. (Iron and Coal Trades Review, 1928, Vol. 117, Sept. 28, pp. 458–459). Illustrated particulars are given of the Bamag-Meguin clarification plant recently installed at the Gutehoffnungshütte at Oberhausen. The plant consists of two tanks each 25 m. diam., a large dredging plant for pumping the slurry, and a double thickening bunker. The water from the washers flows through a trough and is divided between both tanks. From the trough the water flows into a water distributing cylinder, which is adjustable in three sections, and is uniformly divided over the entire depth of the clarification space. From the latter it flows with even and decreasing speed to the circumference of the tanks, depositing at the same time, by sedimentation, all solids which are heavier than water. Before the water overflows into the collecting

trough around the periphery of the tank it flows through a perforated coke filter in which all the finest particles are retained. The slurry is collected in troughs of triangular shape, which feed into various slurry sumps lying under the bottom of the tanks. These sumps are filled by means of a rotating scraper apparatus, the slurry scrapers having the same section as the troughs. The slurry sumps discharge at their lowest points to the slurry pumping system. The slurry suction system connects between the sumps and a pumping plant which lifts the slurry into the thickening bunkers. The bottoms of the slurry thickening bunkers are provided with cast-iron hoppers, shut-off slides, and loading pipes, by means of which the slurry can be loaded into the railway wagons.

Problems in Atmospheric Cooling. G. J. Greenfield. (Paper read before the Coke-Oven Managers' Association, Sept. 29, 1928 : Gas World, 1928, Vol. 89, Nov. 3 (Coking Section), pp. 17–19). The author discusses the problems encountered in the cooling of coke-oven gas at the Fell Coke Works, Consett, and the methods adopted to overcome them.

Economic Aspects of High-Pressure Distribution. S. Lacy. (Gas World, 1928, Vol. 88, June 16, pp. 636–644 ; Gas Journal, 1928, Vol. 182, June 20, pp. 889 896). The subject of gas distribution is discussed under the following headings : definitions of high pressure and high-pressure mains ; determination of the most economic combination of diameter of main and initial pressure ; estimation of maximum rate of delivery and duration of pumping. The question of costs is also dealt with.

Coke-Oven, Town, and Producer-Gas. R. Ray. (Paper read before the Engineering Conference of the Institution of Civil Engineers : Iron and Coal Trades Review, 1928, Vol. 116, June 8, p. 871). The disposal and cost of distribution of gas from coking plants or gasworks are considered. An example is quoted showing that the cost of distribution does not exceed 2d. per 1000 cu. ft. for a distance of 10 miles. The use of producer-gas for the heating of coke-oven batteries is considered to be of questionable value in this country. If a figure of 6d. per 1000 cu. ft. is assumed for coke-oven gas, there is a slight advantage in heating the ovens by producer-gas, which, allowing for a fuel cost of 10s. per ton, can be produced at approximately $5\frac{1}{2}$d. per 1000 cu. ft. The advantages of drawing from a steady supply of crude coke-oven gas or town gas at a reasonable price, if not obvious, merit the consideration of steelworks managers when it is realised that many of the existing producers must soon be reconstructed or renewed ; that the raw materials are, in certain cases, brought considerable distances, and that to this must be added the cost of handling the material and disposing of the ash.

Transmission over Various Distances of Energy in the Form of Coal, Coke, Oil, Gas, and Electricity. E. W. Smith. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Gas Journal, 1928, Vol. 184, Oct. 10, pp. 125–127).

The Problem of the Long-Distance Supply of Gas. Elvers. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 23, pp. 869‑875). The more important long-distance gas supply systems in Germany are described.

Production and Utilisation of Electric Motive Power in the Large Metallurgical Works in the East of France. J. Seigle. (Revue de l'Industrie Minérale, 1928, No. 179, June 1, pp. 234–244 ; No. 180, June 15, pp. 253–264 ; No. 181, July 1, pp. 273–280). The production of electricity from the gases from the blast-furnaces or the coke-ovens is carried out by the intermediary of steam or of gas engines. Both direct and alternating currents are generated and used. Several of the large combined works in the East of France having blast-furnaces, open-hearths, and rolling-mills are able to make such good use of their available gas that they employ practically no raw coal at all.

The Use of Gas in German Iron and Steel Works. Bansen. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 12, pp. 531–532 ; Oct. 19, pp. 565‑566 ; Oct. 26, pp. 616‑617). The utilisation of blast-furnace gas and coke-oven gas is discussed at length.

The Utilisation of Coke-Oven Gases. C. Simon. (Génie Civil, 1928, Vol. 92, June 23, pp. 619‑620). The author discusses briefly the uses to which coke-oven gas may be put.

The Utilisation of Coke-Oven Gas by the Gas Industry. T. P. Ridley. (Paper read before the Fuel Conference of the World Power Conference, Sept. 1928 : Iron and Coal Trades Review, 1928, Sept. 28, pp. 456–457 ; Gas Journal, 1928, Vol. 183, Sept. 26, pp. 659–663).

Coke-Oven Gas for Town Use. (Iron and Coal Trades Review, 1928, Vol. 117, Nov. 9, pp. 686–687). Particulars are given of the coke-oven plant at Auchengeich Colliery, which supplies gas to the Glasgow Corporation. The coke-oven plant consists of two batteries of 14 Wilputte regenerative ovens. The joint throughput of the two batteries is approximately 400 tons per day, and after meeting the heating requirements of the plant there is a daily surplus of gas of about 2,500,000 cu. ft. available for disposal. The coke-oven plant is directly connected to the Provan Gasworks situated about six miles from the ovens.

The Supply of Coke-Oven Gas for Town Use.   J. K. Dickie.   (Paper read before the Coke-Oven Managers' Association : Gas World, 1928, Vol. 89, July 7 (Coking Section), pp. 16–18).

Application of Coke-Oven Gas in the Iron Industry.   G. Bulle. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 755–779). The author deals at considerable length with the utilisation of coke-oven gas in the iron and steel industry under the following headings : The properties, composition, and calorific value of the gas ; the use of coke-oven gas as fuel in open-hearth furnaces and other metallurgical furnaces ; for the generation of power, and for domestic heating ; burners ; storage ; distribution ; and measurement.   Coke-oven gas in general consists of 45 to 65 per cent. H_2, 20 to 35 per cent. CH_4, and 5 to 7 per cent. CO.   There are never lacking small quantities of CO_2 and N_2, the latter being due to leakage of air in the coke chamber.   When the ovens are new and in good repair the N_2 may be 3 to 5 per cent. and the CO_2 1 to 2 per cent. of the gas, but with old ovens the N_2 may go up to over 15 per cent. and the CO_2 to 5 per cent.   Small quantities of free oxygen are also seldom lacking.   A considerable portion of the sulphur of the coal goes into the coke-oven gas, so that the gas (in Germany) contains 6 to 9 grm. per cu. m., but in furnaces making or treating ordinary kinds of steel this proportion of sulphur is not injurious.   In the open-hearth furnace coke-oven gas is used either as an addition to producer-gas or is mixed with blast-furnace gas (mixed gas), or is used alone as straight gas.   Of these alternatives, mixed gas is the most commonly adopted, since it provides a means of utilising excess blast-furnace gas as well as coke-oven gas.   In many instances the mixture consists of coke-oven, blast-furnace, and producer-gas, the latter being added in order to provide against fluctuations in the supply of the other two and also to keep the producer plant running as a standby.   Figures are given showing that, using straight coke-oven gas cold with a calorific value of 3900 to 4100 kg. cal. per cu. m., for firing a 100-ton stationary furnace working the scrap process with liquid pig, the gas consumption averaged 300 cu. m. per ton of steel produced.   Data are likewise given for mill furnaces, soaking pits, and annealing furnaces.   The following types of burners are illustrated by sectional drawings : Gross, Gako, Bader and Salau (two types), Selas, Schilde, Röhrig and Schneider, Herberholz (turbo-burner), West-deutsche Industrie-Wärme, and Mecker-Dujardin (Bunsen type).   The particular features and control of each type are described.

The Operation of the Siemens-Martin Furnace with Coke-Oven Gas. G. Bulle.   (Stahl und Eisen, 1928, Vol. 48, Sept. 27, pp. 1353–1362). After a short historical note, the author discusses the properties of coke-oven gas in comparison with those of other fuels used in the open-hearth, such as the composition, calorific value, supply of heat and temperatures, preheating, density, sulphur content, &c.   He then

1928—ii.   U

deals with the operation of the furnace with mixtures of coke-oven and blast-furnace gases with and without producer-gas, and the use of coke-oven gas as an addition to producer-gas. He also considers the use of cold gas. The high calorific value of coke-oven gas gives rise to the expectation of good melting results even when only moderately preheated, but the lack of colour in the flame is unfavourable to good heat radiation on to the bath. More intensive preheating decomposes the gas into carbon and mixtures of gases rich in hydrogen and carbon monoxide, but the heat of combustion rises at the same time, so that stronger preheating is not objectionable. A number of works are firing their open-hearths with cold gas, which is introduced into the preheated air supply by lateral water-cooled burners. Cold-gas furnaces differ from the usual design in that the port block is shorter and the regenerators are arranged in pairs or in tandem. The quantity of gas used in the mixed-gas and cold-gas processes compares favourably with producer-gas practice.

The Operation of the Siemens-Martin Furnace with Mixed-Gas Firing. W. Heiligenstaedt. (Stahl und Eisen, 1928, Vol. 48, Oct. 18, pp. 1465–1471). The author deals with the following aspects of the subject : The dependence of the amount of heat transferred from the flames to the charge upon the temperature of combustion and upon the radiation from the flames ; the influence of the soot content of the gas on the intensity of the flame radiation ; the source and formation of free carbon in producer-gas and mixed gas (mixture of coke-oven and blast-furnace gas) ; the necessity for more strongly preheating mixed gas to decompose the methane ; conclusions as to the proportions of the hearth, &c., to obtain greater heat transference ; the use of catalysts (nickel) to precipitate carbon out of mixed gas, *i.e.* produce soot ; the supply of the gases from the coke-oven and blast-furnace plants required due to the introduction of mixed-gas firing ; control and regulation of the gas mixture.

On the Use of Coke-Oven Gas in Small Furnaces and Heating Apparatus. H. Bleibtreu. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 99–107). The advantages of coke-oven gas as a fuel are discussed ; the inadequacy of the older type of furnace construction is pointed out. Modern small furnaces and heating apparatus are described and illustrated by means of photographs. A comparison is made of the cost of heating by the use of coal, oil, coke-oven gas, coal dust, electricity, and small coke.

Investigation of the Heat Conditions of a Modern Morgan Reheating Furnace of the Siemens' Type, Fired with Blast-Furnace Gas. M. Steffes. (Stahl und Eisen, 1928, Vol. 48, May 31, pp. 718–721). The continuous furnace on which the trials were made served a 10-in. light mill, rolling wire from 12·7 mm. to 5 mm., and the blooms, about

$2\frac{1}{2}$ in. square, were 6 cwt. in weight. The heating was with blast-furnace gas of 868 to 905 kg. cal. per cu. m. By preheating the gas and air any desired temperature can be obtained, up to the limit which the brickwork at the ports will stand. The consumption of gas without a fan was 455 cu. m. per ton of billets heated from the cold to 1210° C. With a fan the gas per ton of billets was 405 cu. m., and the average temperature of the billets when drawn was 1224°.

Mill Furnaces Heated with Blast-Furnace Gas. J. Meiser. (Stahl und Eisen, 1928, Vol. 48, June 21, pp. 822–823). A note describing the reconstruction of coal-fired reheating furnaces by converting them into regenerative gas-fired furnaces. (*See* Archiv für das Eisenhütten-wesen, 1928, Vol. 1, Apr., pp. 639–646.) The dimensions of the new furnaces are stated. Soaking pits were also changed over to gas-firing, the gas consumption being 240 cu. m. per ton of ingots, equal to a coal consumption of 3·4 per cent. The reheating furnaces for the mill rolling medium sizes averaged 450 cu. m. of gas per ton of steel, and that for the light sections averaged 830 cu. m. per ton.

Tests of a Reheating Furnace with Metallic Recuperators Fired with Blast-Furnace Gas. A. Lemonnier. (Chaleur et Industrie, 1928, Vol. 9, Aug., pp. 463–464). The tests were carried out at the Differ-dange Works. The furnace used had a hearth measuring $450 \times 350 \times 250$ mm., the overall dimensions, including the regenerators, being 1·05 m. long by 0·5 m. wide and 1·70 m. high ; the two recuperators together occupied $600 \times 150 \times 650$ mm. The temperature of the furnace was raised to 1215° C., and steel ingots totalling 17·5 kg. were charged into it. These were heated in 20 min., the blast-furnace gas being consumed at the rate of 40 cu. m. per hr. On the withdrawal of the ingots, the temperature of the hearth was found to have dropped 40° C. The efficiency of the recuperators was good ; the increase of temperature of the air and of the gas was practically equal to the drop in temperature of the waste gases.

Regulating Tests Carried Out on Two Blast-Furnace Gas Burners. M. Steffes. (Revue Technique Luxembourgeoise, 1928, Vol. 20, May and June, pp. 57–60). The author records experiments carried out on two burners of the Dingler type, burning blast-furnace gas, in which the degree of regulation, efficiency, sensitiveness, and capacity of the burners were tested. The tests showed that the burners ensure an intimate mixture of gas and air, so permitting complete combustion. The burners adapt themselves easily to variations arising in service.

Industrial Tests made on the Cockerill No. 2 Blower Gas Engine Group installed at the Gas Blower Central Station of the Belval Works belonging to the Société Métallurgique des Terres Rouges. M. Steffes and A. Graff. (Chaleur et Industrie, 1928, Vol. 9, July, pp. 391–410).

Gas consumption, blast volume, power, air for combustion, cooling water, and the thermal balance were some of the matters investigated.

The Gas Engine in the Iron and Steel Industry. T. B. Morley. (World Power, 1928, Vol. 10, Nov., pp. 537–542). The author discusses the advantages of the gas engine, as a means of utilising blast-furnace gas, over other systems, and touches on the design and performance of the modern gas engine and the cost of power production.

The Large Gas Engine for Electric Power Stations. (Engineering and Boiler House Review, 1928, Vol. 42, Aug., pp. 102–105 ; Sept., pp. 152–155). A consideration of the economic possibilities of using large gas engines as supplementary to the main steam turbines when large volumes of combustible gas are available.

LIQUID FUEL.

Scientific Foundations of the Refining of Petroleum. A. E. Dunstan. (Journal of the Royal Society of Arts, 1928, Vol. 76, Aug. 3, pp. 922–942 ; Aug. 10, pp. 945–963 ; Aug. 17, pp. 965–981 ; Aug. 24, pp. 985–998 ; Aug. 31, pp. 1001–1024).

Composition of Petroleum and its Products. G. A. Burrell. (Fuel in Science and Practice, 1928, Vol. 7, Sept., pp. 416–423).

Influence of Oxygen on the Ignition of Liquid Fuels. H. Pahl. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 16, pp. 857–860). The effect of the amount of oxygen present in the air supplied to support combustion on the ignition characteristics of oils is discussed.

Experimental Oil-Shale Plant of the Bureau of Mines. M. J. Gavin. (Industrial and Engineering Chemistry, 1928, Vol. 20, Aug., pp. 784–791). A description is given of the experimental oil-shale plant operated by the United States Bureau of Mines at Rulison, Colorado, during 1926 and 1927. The oil-producing equipment consists of two retorts, a standard Pumpherston retort of the type in commercial use in Scotland, and an N–T–U retort similar to the units used by the N–T–U Company at Casmalia, California. Analyses of the oils produced by both retorts are given. The results obtained thus far have demonstrated the utility of both retorts as large-scale units, and the work is to be continued until June 30, 1929, with some modifications in retort design and methods of operation to make the process more suitable for

American shales, and to establish the economic capacities of the two methods.

Report on the Pritchard Process for the Distillation of Oil Shale. R. E. Gilmore and A. A. Swinnerton. (Canada, Department of Mines, Mines Branch. Investigations of Fuels and Fuel Testing, 1926, pp. 106–120).

Necessity for Proper Atomisation of Oil. J. R. Miller. (Heat-Treating and Forging, 1928, Vol. 14, Apr., p. 427). Trouble was experienced with a four-hole oil-fired soaking pit ; the oil was atomised at some distance from the furnace, and in the long carry some of the oil re-formed drops which were projected through the burner on to the hot metal, where it carburised the surface and caused hard spots. Near the firing hole a 45° fitting was inserted ; the straight branch led into a reducer and a $\frac{1}{4}$-in. pipe carried the oil drops, while the 45° branch led on with a $\frac{1}{2}$-in. pipe to carry the still atomised part of the mixture. Both pipes led into a second atomiser at the firing hole, and here the mixture was used to reatomise the separated oil.

Synthetic Motor Spirits : Problem of the Rational Utilisation of Mineral Fuels. R. Brunschwig. (Chaleur et Industrie, 1928, Vol. 9, Mar., pp. 143–151). By the term " synthetic motor spirits " the author distinguishes those hydrocarbons, alcohols, and other liquids which are prepared from solid mineral fuels, and which are particularly intended to replace petrol as a fuel for the internal combustion engine. The processes for their production may be grouped as follows : High-temperature carbonisation, low-temperature carbonisation, transformation of the tars obtained into lighter products, hydrogenation of the solid fuel, and treatment of the gaseous products obtained from the solid fuel by carbonisation or gasification ; the author discusses the subject under these broad headings.

The Chemical Treatment of Coal on the Continent. (Engineer, 1928, Vol. 145, Apr. 27, p. 455). A brief review of the developments on the Continent in the synthetic production of liquid fuels and nitrogenous products from coal and lignite.

Recent Developments in the Production of Motor Fuels from Coal. A. C. Fieldner. (Fuel in Science and Practice, 1928, Vol. 7, Nov., pp. 492–501). The author summarises the scientific and commercial developments in the production of motor fuel from coal.

Report on the Bergius Process for the Liquefaction of Coal. H. O. Askew. (New Zealand Journal of Science and Technology, 1928, Vol. 9, Apr., pp. 321–334 ; Vol. 10, May, pp. 1–16). A review of the work of various investigators, showing developments that have been carried

out in the past few years in the Bergius process. The medium-scale plant, similar to that used by Bergius at Mannheim-Rheinau, installed at the Fuel Research Station, Greenwich, is described. The chemistry of the process and its products, and the economics of the method, are discussed. An appendix on the conversion of coal into oils by sodium formate and carbon monoxide is based on the work of Fischer.

The Attack of Coals and of Products of Vegetable Origin. A. Skopnik. (Teer, 1927, Vol. 25, Mar. 1, pp. 97–101). In the presence of anthracene oil, certain combustibles, dried and reduced to the size of nuts, are transformed into light oils and resinous matters containing colloidal carbon when heated to 350° C. and stirred. With fat coals the products are : 8 to 12 per cent. of light oils containing phenols, nitrogenated bases, aliphatic, unsaturated and aromatic hydrocarbons ; a resin which is plastic at 50° C. and resembles tar at 70° C., containing 23 per cent. of colloidal carbon and saponifiable ethers ; anthracene oils which have not reacted ; and a small quantity of gas. The process is not applicable to cannel coal or lean coals ; on the other hand, lignites, peat, wood, and straw are transformed, and in the case of the peat and wood large quantities of acetic acid, methane, acetone, and other oxidised products of the pyrogenation of the cellulose are obtained.

Study of the Action of Ferrous Catalysts on Mixtures of Carbon Monoxide and Hydrogen. E. Audibert and A. Raineau. (Revue de l'Industrie Minérale, 1928, No. 182, July 15, pp. 285–314). The authors have carried out experiments having for their aim the production of organic liquids by the interaction of hydrogen and carbon monoxide initiated by a catalyst. The first part of the paper is devoted to the discussion of the various catalysts available. The various tests performed are described. On passing mixtures of CO and H_2 over the catalysts containing ferric oxide at pressures around 150 atmospheres, organic compounds, consisting of hydrocarbons (saturated and unsaturated, liquid and gaseous) and aliphatic alcohols, were obtained. The efficiency was low, and the authors experienced considerable difficulty in finding the exact conditions for the reaction to proceed. It appeared to be essential that the iron oxide should not become reduced, but alterations of the temperature were unsuccessful in satisfying this condition.

Theory and Practice of the Oil-Firing of Metallurgical Furnaces. E. Zimmermann. (Giesserei-Zeitung, 1928, Vol. 25, Aug. 1, pp. 451–459 ; Aug. 15, pp. 483–485). The author deals with the following aspects of his subject : The development of the American technique of oil-firing in comparison with European conditions ; liquid fuels, their composition and the determination of their heat values ; flash points and flame temperatures of oils ; the process of combustion ; the influence of the air volume on the character and temperature of the

flame, and on the losses in metallurgical furnaces ; calculation of the theoretical air volume ; the atomisation of the fuel oil and its influence on the speed of combustion ; critical investigation of atomisers ; calculation of the waste gases ; determination of the air volume from the analysis of the waste gases in conjunction with the analysis of the fuel and of the air ; flame and furnace temperatures ; influence of heated secondary air on the flame temperature and on the consumption of fuel ; heat losses and heat balance ; losses in oil-fired furnaces ; critical comparison of various furnace constructions ; general instructions for the manipulation of oil-fired melting furnaces ; temperature measurements.

The Use of Liquid Fuel in Open-Hearth Furnaces. M. J. Conway. (Journal of the Institute of Fuel, 1928, Vol. 2, Oct., pp. 100–103). Coal-tar is not commonly used except for economic reasons, but the residua from the cracking stills in the manufacture of lubricating oils and gasolene from crude oils are now being used advantageously as open-hearth fuels. Either paraffin or asphaltic base oils can be used, provided the sulphur content is not excessive. Fuel oil to be used economically must be correctly atomised. Heavy oils are the more economical owing to their greater thermal value per gallon. A typical specification for heavy fuel oil adopted by the United States Government Specification Board is given. A typical liquid fuel installation is illustrated. The success of fuel oil for open-hearth furnaces depends upon constant pressure and constant temperature. Constant pressure can be maintained by the use of a pressure unloading valve or pressure regulating valve placed at some point on the delivery line beyond the most distant furnace, where it will discharge the surplus oil into the return line. Constant temperature can be maintained by thermostatic control of the oil leaving the heater and the steam entering the heater, this heater being preferably situated on the discharge side of the pump, utilising the low-pressure exhaust from the pump turbines with a high-pressure connection for starting up or emergency purposes should the spare pumping unit be electrically driven. The temperature of the oil required to produce the best viscosity for atomisation is usually not more than 160° F. at the burner for the heaviest liquid fuel.

The Flow and Measurement of Petroleum Products in Pipe Lines. S. W. Adey. (Journal of the Institution of Petroleum Technologists, 1928, Vol. 14, pp. 222–235).

PRODUCTION OF IRON.

PIG IRON.

New Blast-Furnaces at the Old Works of the Stanton Ironworks Co., Ltd. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 21, pp. 289–294 ; Foundry Trade Journal, 1928, Vol. 39, Sept. 13, pp. 183–186). A complete illustrated account of the new blast-furnace plant of the Stanton Ironworks Co., Ltd. The plant consists of three blast-furnaces having 11-ft. hearths, 19-ft. diam. boshes, 13-ft. diam. throats, 9-ft. diam. bells, and they are 75 ft. high to the charging level. They are designed to produce 1000 tons of iron per week, working on Midland ores containing an average of 28 to 30 per cent. of iron. The furnace tops are of the double bell and revolving distributor type. The furnaces are charged by means of a double skip hoist. There are two turbo-blowers with a third acting as a standby. Each blower delivers 28,000 cu. ft. of air per min. at $9\frac{1}{2}$-lb. pressure. There are eight calcining kilns, the arrangement of which is shown.

The Sydney Steel Plant, Nova Scotia. (Engineer, 1928, Vol. 145, June 22, pp. 681–683). An account is given of the equipment of this Canadian steel plant. There are six blast-furnaces charged by means of skip buckets ; the furnaces are 80 ft. high, and the hearths vary from 15 to 17 ft. in diam. Each furnace is fitted with 12 tuyeres ; the air is preheated to about 1100° F., and is blown at 11 lb. per sq. in. pressure. About 40 per cent. of the gas is burnt at the stoves, the remainder being used under boilers. Large quantities of salt water are used for cooling and condensing purposes, and the pump-house contains five centrifugal pumps having a combined capacity of 70 million gal. per day. The molten metal from the furnaces is held in a 300-ton mixer. There are 12 open-hearth furnaces, 10 of 50-tons and 2 of 100-tons capacity, all of the tilting type. Brief particulars are also included of the rolling-mills.

Blast-Furnaces on the Burgers System, with Water-Cooled Metallic Shaft, without Internal Refractory. E. de Loisy. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Oct., pp. 557–562). The author has made tests between two blast-furnaces in the one works, one being refractory lined in the usual way, the other being of the Burgers thin-wall type. The daily output of the latter was somewhat below that of the normal furnace, but this was accounted for by the fact that the Cowper stoves serving it were somewhat smaller than those attached

to the refractory-lined furnace. The Burgers furnace used less ore per ton of iron made, due to its smaller dust losses.

The Blast-Furnaces of the Mineral Basin of Lorraine-Luxemburg. A. Wagener. (Fuel Economist, 1928, Vol. 3, May, pp. 513–515). The concluding instalment of an abridged translation of an article describing blast-furnace design and operation in this region. The original appeared in Revue Technique Luxembourgeoise, 1927, Vol. 19, June, Special Number, pp. 15–27.

How Motions of Ore Bridges are Controlled. W. C. Raube. (Iron Trade Review, 1928, Vol. 83, Sept. 6, pp. 568–569, 616). Particulars are given of an up-to-date installation of motors, brakes, and control on an ore bridge at the Perry Ironworks, Erie, Pa.

Charging Blast-Furnaces. G. Descamps. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 31, p. 294). A short account is given of Belgian practice in the charging of blast-furnaces.

Large-Scale Experiments to Determine the Economic Working of Blast-Furnace Stoves. M. Steffes. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 1–10). The ironworks of Terres Rouges at Esch, Luxemburg, have five blast-furnaces, with a daily production of 310 to 320 tons each. Each blast-furnace has five stoves lined with ordinary firebrick and working on natural draft. One of the five is kept in reserve. The blast temperature at the stove is 925° at the commencement, and it sinks to about 725° at the change-over. The blast-pressure is 9 lb. The stove selected for the trials had been entirely relined and the top part insulated with special bricks. The stove was 33 m. high, and 6·63 m. in diam. inside the lining. The weight of the checkers was 470 tons, occupying 497 cu. m., the passages measured 145×145 mm. ($5\frac{3}{4}$ in.), and the number of passages was 445. The complete results of the efficiency tests are presented in tabular form. In general, during the period under gas, the heat stored was 79·2 per cent. of the total heat introduced, the chimney losses were 12·5 per cent., and the losses in the mains, by radiation and in changing over, were 8·3 per cent. During the period under blast the proportion of heat given up was 92·8 per cent., and the losses in the mains, by radiation and in changing over, were 7·2 per cent. The total efficiency over the double period is put at 78 per cent. while working under the test conditions, and for ordinary daily operation it is estimated at 70 per cent. By insulating the upper part of the stove the losses by conduction and radiation were reckoned to be reduced by 10 per cent.

The [Temperature] Constancy of Stoves. W. Nusselt. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, July 28, pp. 1052–1054). The subject is treated mathematically.

Economy in the Heating of Cowper Stoves. (Iron and Coal Trades Review, 1928, Vol. 117, July 20, pp. 79–80). It is pointed out that although the P.S.S. system is an advantageous one for heating blast-furnace stoves, it is an expensive one to install, and particulars are given of a system which can be adopted at very low cost. It consists of joining two stoves together by means of a tube, so that the four stoves serving the blast-furnace are connected together in pairs ; one pair works on gas and the other on air alternatively. On heating, the gas burns in the shaft of the first stove, passes through the checker-work and through the connecting tube into the second stove, where it continues to give up its heat before escaping to the chimney at a much-reduced temperature. When the blast is to be heated it flows in a direction opposite to that taken by the gas. The method has been applied with success in Luxemburg, Lorraine, and Belgium, and the results obtained at the works of the Société des Hauts Fourneaux et Aciéries de Differdange with four stoves and with the stoves coupled in pairs are tabulated. The results show : (1) an increase in the temperature of the blast ; (2) an increase in the output of iron ; (3) a decrease in the ratio of coke to iron ; (4) a fall in the temperature of the waste gases ; (5) an increase in the thermal efficiency of the stove ; and (6) a reduction in the consumption of gas for heating the stoves.

Alterations in Cowper Stoves in Order to Improve their Efficiency. A. Cousin. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Apr., pp. 231–234). The author publishes two diagrams which are intended to be of assistance to those who are building or altering Cowper stoves ; the diagrams supply the answer to questions which may arise relating to the consumption of gas, the temperature of the blast, and to the calorific efficiency of the stoves.

Steinbart Patent Automatic Pressure-Combustion Control System. (Iron and Coal Trades Review, 1928, Vol. 117, Sept. 14, pp. 360–361). The Steinbart system applied to hot-blast stoves has resulted in increased blast temperatures and a decrease in the number of stoves required at the Acklam Iron and Steel Works, where the system is installed. The blast temperatures have been increased by approximately 150° F., whilst the estimated saving in gas is equal to 20 per cent. The automatic regulator allows the load on the stoves to be varied without interfering with the combustion efficiency, and owing to the utilisation of the whole of the checker brickwork available, increased stove efficiencies are obtained.

Brown-Boveri Blower at Braddock. (Iron Age, 1928, Vol. 122, Aug. 16, pp. 395–397). An illustrated description is given of the Brown-Boveri blast-furnace turbo-blower installed at the Edgar Thomson Works of the Carnegie Steel Co. The unit is of the four-

bearing type, and consists of a five-stage, single-inlet, uncooled centri-fugal blower direct connected by a semi-flexible claw type coupling to a combined impulse and reaction steam turbine, designed to operate with steam at 225 lb. per sq. in. gauge and 150° F. superheat, exhaust-ing into a vacuum of 28 to $28\frac{1}{2}$ in. The set is designed to blow a furnace of 750 tons of pig iron daily capacity. A maximum operating load was specified as 60,000 cu. ft. a minute at a blast pressure of 30-lb. gauge. In service the set has shown itself capable of delivering an inlet volume of 70,000 cu. ft. a minute at 30 lb. The only cooling water required for the set is that for the oil coolers, two of which are furnished, connected in parallel, so that either one can be cleaned without shutting down the set.

A New Theory of the Blast-Furnace Process. F. Wüst. (Revue Technique Luxembourgeoise, 1928, Vol. 20, July–Aug., pp. 81–92 ; Stahl und Eisen, 1928, Vol. 48, Sept. 13, pp. 1273–1287). A discussion of the reactions in the blast-furnace. The author's new theory was published in Journ. I. and S.I., 1927, No. II. p. 65, but the present paper gives more complete details of experiments carried out on various furnaces producing a variety of different pig irons.

Comparisons of the Results of Blast-Furnace Working. E. C. Evans and F. J. Bailey. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 207–216). An abridged translation into German of the paper presented by the authors to the Iron and Steel Institute (*see* Journ. I. and S.I., 1928, No. I. pp. 53–116).

Some Parallels and Comparisons in Blast-Furnace and Cupola Practice. J. E. Fletcher. (Fuel Economy Review, 1928, Vol. 7, pp. 55–64). The subject is discussed under the following headings : Economy of rapid melting and smelting ; modern tendency in design ; composition of gases escaping at furnace throat ; indirect reaction ; direct reaction ; rate of driving and air supply.

A Study of Sulphur in the Basic Process. H. A. Geiger. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1201–1203, 1208 ; Oct., pp. 1319–1321). The work of various investigators on the sources of sulphur in pig iron and conditions of its elimination in the blast-furnace is summarised and discussed, with special refer-ence to the temperature and slags. The action of manganese as a desulphuriser is also discussed.

The Reactions in the Blast-Furnace in the Light of Sintering and of Carbon Deposition. B. Osann. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 137–143). Small lumps of various ores, coke, and marble were heated together in a crucible for various periods, and the resulting masses were then broken and examined. It was concluded

that the process of the reduction of iron ores in the blast-furnace passed through the sintering stage, and that it was dependent only on the deposition of the carbon from the carbon monoxide gas. The experiments also explained the course of the carburisation of the pig iron, and of its dependence upon the size of the pieces of ore and reducing agent. The theory of sintering and carbon deposition in the blast-furnace provided an explanation for various effects, such as the production of malleable iron and kish in the blast-furnace, scaffolding, high top temperature, and the practice of the puddling process.

Carbon Deposition near Furnace Top. F. C. Howard. (Iron Age, 1928, Vol. 122, Aug. 2, p. 271). According to the author blast-furnace gases are accountable for most of the carbon deposition near the furnace top.

Importance of Gas-Solid Contact in the Blast-Furnace. T. L. Joseph. (Fuels and Furnaces, 1928, Vol. 6, May, pp. 635–640). A discussion of the factors affecting the rate of reduction; stock distribution; particle size; effect of localised combustion at the tuyeres, and hearth reactions.

Gas Analysis Index to Furnace Operation. G. V. Slottman. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 615–616). An abstract of Report No. 86 of the Blast-Furnace Committee of the Verein deutscher Eisenhüttenleute, which deals with the determination of material and heat balances of the blast-furnace, based on the gas analysis and air volume. The original report appeared in Archiv für das Eisenhüttenwesen, 1927, Vol. 1, Oct., pp. 245–266.

A New Heat Diagram for the Blast-Furnace. P. Reichardt. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Sept., pp. 521–539). A translation into French of a paper which originally appeared in Archiv für das Eisenhüttenwesen. (*See* Journ. I. and S.I., 1927, No. II. p. 518.)

Blast-Furnace Gas as Condition Indicator. W. G. Imhoff. (Iron Age, 1928, Vol. 121, June 14, pp. 1686–1687; Vol. 122, July 26, pp. 203–204; Aug. 16, pp. 393–394). A series of three articles dealing with blast-furnace operation. The author shows how the blast-furnace operator can keep control of the furnace by close observation of the character of the gases.

Hydrogen Content of Blast-Furnace Gas. B. Osann. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 673–675). By determining the amount of moisture introduced into the blast-furnace in the blast, in the coke, in the clay stopper of the tapping hole, and by leakage at the tuyeres, the quantity of hydrogen entering the furnace can be calculated, and on analysing the waste gases it will be found

that the proportion of hydrogen in the gas is about the same as the calculated amount entering the furnace. The explanation is that the hydrogen which forms in the lower part of the furnace takes no part in the reduction reactions, while the water contained in the charge does not undergo decomposition at all.

Modern Scientific Principles in the Working of Blast-Furnaces of Large Output. M. Derclaye. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Apr., pp. 195–211). The conclusion of a series of articles (*see* Journ. I. and S.I., 1928, No. I. p. 779). In the present instalment the author discusses the creation of a zone of fusion with a view to accelerating the production, and in this connection touches on the question of the combustibility and reactivity of coke. Finally, he reviews the efforts made in Europe to run blast-furnaces on modern scientific principles as outlined in the paper.

Observations on European Iron and Steel Conditions. C. A. Meissner. (Paper read before the American Iron and Steel Institute, Oct. 26, 1928). The author presents his impressions of the developments in iron and steel manufacture in Europe, and gives particulars of the equipment and practice at the Bagnoli plant, Piombino, the Terni steel plant in Italy, and the Brown-Boveri works at Baden in Switzerland. The main portion of the paper is devoted to blast-furnace design and operation in Germany and Luxemburg. Illustrations are included of German blast-furnace lines. Little scrap is charged in German blast-furnaces because of difficulties with the bucket tops generally used. At the Hamborn works, Neeland bucket-type filling is used on all furnaces, and is common throughout Europe on the larger furnaces. At the Hamborn furnaces, which are chiefly discussed, the daily average production on 16 ft. 5 in. hearths has been as high as 835 tons, which is attributed largely to the open nature of the burden. A comparison is also made of German and American practice, and the dimensions of some typical American blast-furnaces are tabulated.

The Lessons of the Recent Explosions in Blast-Furnace Works. A. Wagner. (Stahl und Eisen, 1928, Vol. 48, Aug. 23, pp. 1153–1159 ; Aug. 30, pp. 1200–1202). Explosions in blast-furnace works at Völklingen and Oberhausen are discussed. In the former case the opinion is held that the mishap was due to an explosion caused probably by an endothermic reaction between finely divided carbon and oxide ores, the mixture of which was brought about by the collapse of a scaffold high up in the furnace. The hanging of the charge in the upper part of the shaft is regarded as particularly dangerous. Suggestions for the prevention of scaffolding as well as for the protection of the shaft from damage by explosion are put forward. The explosion at the Oberhausen Works occurred in the air-main of one of the stoves, and is to be attributed to the presence of an explosive gas mixture in the

main during the reversal of the stoves, due to the omission to close one of the valves. It is suggested that the danger of a repetition of such an explosion will be avoided by suitably coupling the gear operating the hot-blast and cold-blast valves.

The Metallurgy of Casting Direct from the Blast-Furnace. A. Michel. (Giesserei-Zeitung, 1928, Vol. 25, May 1, pp. 279–281). The author discusses the development and technique of the direct casting of iron from the blast-furnace. He points out the difference in the quality of cast iron from the first and second meltings, and touches on the question of methods for the production of a high quality cast iron.

The Manufacture of Ferro-Manganese at the Makiewka Works (South Russia). M. V. G. Kotelnikoff. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Oct., pp. 541–556). The article gives the production results of a campaign of seventeen months. The blast-furnace and its accessories, the process of blowing it in, the raw materials, a first (earlier) campaign with basic slags, the increase of the basicity by the addition of dolomite, the influence of the dolomite on the cost, the second campaign (seventeen months) with acid slags, the distribution of the manganese between the metal, the slag, and the gas, are described and discussed. The two campaigns are compared ; notes are given concerning the gas, the dust, and the slags, and from the figures given the author draws conclusions in favour of the use of acid slags. The blast-furnace was built with a Burgers water-cooled metallic shaft without internal refractory ; the shaft gave excellent service, and the furnace was finally blown out on account of the failure of the hearth.

DIRECT PROCESSES.

The Speed of Reduction of Iron Ores in Currents of Gases. H. H. Meyer. (Mitteilungen aus dem Kaiser-Wilhelm Institut für Eisenforschung, 1928, Vol. 10, No. 7, pp. 107–116). Experiments to determine the speed of reduction of two iron ores by streams of reducing gases are described. A distinction is drawn between the speed of reaction and the speed of reduction. The latter is controlled by the sintering of the reduced iron, the deposition of carbon, and the speed of the gas diffusion. Iron reduced by hydrogen begins to sinter at $650°$ C. ; as a result, the diffusion of the gas to the unreduced interior is hindered, the hindrance increasing with the speed and intensity of the sintering. Above $900°$ C. the velocity of reduction increases again, as the diffusion of hydrogen in the γ range is greater. The speed of reduction by CO is unaffected by sintering, as the latter is hindered

by carbon precipitation. Except in the temperature range where reduction by hydrogen is impeded by sintering, that gas reduces iron ore more rapidly than CO. For technical processes in which the material is reduced at increasing temperatures, the most satisfactory conditions are obtained by the use of a hydrogen-carbon-monoxide mixture, as the carbon precipitate hinders the sintering and the hydrogen speeds up the reduction. With magnetite carbon precipitated principally on the surface; the higher the temperature the greater the degree of reduction that was necessary to cause the precipitation to occur. Hydrogen increased the precipitation. Similar results were obtained with minette ore, except that the speed of reduction was greater and the precipitation of carbon occurred within the pieces of ore, both on account of the greater porosity of the material. At 1000° C. the higher silica content caused the formation of silicates, which stopped up the pores. The speed of reaction can be studied at the commencement of reduction, when sintering, carbon deposition, &c., play no part. The reaction velocity of hydrogen at all temperatures, and with both the above ores, is about four times that of CO; Nernst's law for speeds of reaction in heterogeneous systems applies to the case. It was shown that during the reduction by a hydrogen-carbon-monoxide mixture, most of the reduction was caused by the hydrogen, and the water produced was reconverted into hydrogen by the carbon monoxide.

The Flodin-Gustafsson Direct Process. S. Kalling. (Jernkontorets Annaler, 1927, Vol. 111, pp. 35–74 ; Stahl und Eisen, 1928, Vol. 48, June 14, pp. 798–800). A detailed report on this process has now appeared. The experimental furnace at Hagfors of 200 to 300 kw. was considered to have given such good results as to justify the construction of a new furnace of 1500 to 2000 kw., which, however, is still of an experimental nature. The product is mainly of importance for the open-hearth process as a substitute for scrap. The briquetting of the raw materials has hitherto been one of the chief difficulties. The briquettes are compounded of " slig," containing about 63·5 per cent. iron, with sulphur 0·008 and phosphorus 0·004 per cent. ; charcoal ground to 5-mm. size is added in sufficient quantity to reduce and carburise the iron, and lime is used as a binder. The mass is mixed in a pug-mill and pressed into rounds which are broken into briquettes about 3 in. long. The furnace is contained in a steel-plate shell about 14 ft. 3 in. diam., and 8 ft. 6 in. high ; the lining of firebrick and magnesite brick is 16 in. thick, and the crown 12 in. thick. Three electrodes pass vertically through the crown. The briquettes are fed through two vertical square shafts with hoppers at the top, and the gases of reduction escape through the same shafts, being led off through a downtake just below the small bell closing the hopper. The composition of the gases averages about CO_2 4·0, O_2 0·8, CO 73·8, H_2 20 per cent., the rest being methane and nitrogen. The total charcoal consumption

per ton of iron produced is 416 kg., allowing for an iron containing 0·5 per cent. carbon. The analysis of the actual product is carbon 0·06 to 0·5, silicon 0 to 0·04, manganese 0·27 to 0·46, phosphorus 0·004 to 0·006, sulphur 0·050 to 0·034 per cent. The electric energy consumed is 2700 kw.-hr. per ton of steel, costing 0·005 krone per kw.-hr. ; that is, the total cost of current per ton of iron is 13·50 krone. The cost of production of 1 ton of iron by this direct process works out at 91·10 krone, after allowing a credit of 5 krone for the gas, which is mainly used for drying the briquettes. The cost of electrically produced pig iron at the same works, the wages, raw materials, and current being at the same rates, works out at 74·14 krone. Technically this direct process is successful, and the data given represent the results of a five weeks' run. The production per day ranged from 10 to 14·5 tons. But whether it will prove economically successful still remains to be judged. Various improvements have lately been made with a view to cheapening the cost of production, but these are not specified.

IRON INDUSTRIES.

The Iron and Steel Industry in the Light of the English Economic Committee. H. Niebuhr. (Stahl und Eisen, 1928, Vol. 48, Aug. 9, pp. 1093–1096). A discussion of the interim report of the Balfour Committee on the iron and steel industry, the manufacture of machinery, electro-technics, and shipbuilding.

Presidential Address. F. S. Wilkinson (Proceedings of the Staffordshire Iron and Steel Institute, 1927–28, Vol. 43, pp. 2–11). Complete particulars are given of the firms owning blast-furnaces in the Staffordshire district in the year 1862, showing the number of furnaces in and out of blast.   The mills and forges in the South Stafford-shire district with the number of puddling furnaces in the same year are also given.

Amalgamations and Cartels in the Iron, Steel, and Allied Industries in Germany. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 12, pp. 544–545). Particulars are given of the industrial amalgamations that have taken place in Germany. The formation of syndicates and price cartels is also dealt with   The information given is taken from a report on the economic and financial conditions in Germany by C. J. Kavanagh, issued by the Department of Overseas Trade.

Organisation of the German Steel Ingot Syndicate. (Iron and Coal Trades Review, 1928, Vol. 117, July 27, p. 119). The organisation of the Steel Ingot Syndicate is briefly discussed, and a table is given

showing the participation figures of the firms who are members of the German Union of Steelworks (Stahlwerks Verband). The table also shows the dates on which their various agreements expire. Another table shows the tonnages of rolled products which can be produced from 1000 tons of ingots, and also the tonnage of ingots required to produce 1000 tons of rolled products.

The Iron Industry of the Saar. E. L. Antz. (Die Giesserei, 1928, Vol. 15, June 8, pp. 543–544). The history of the development of the newer German ironworks in the Saar is reviewed. After a long period of inactivity the industry resumed its progress in 1880.

What is the Status To-Day of France's Iron and Steel Industry? H. Hermanns. (Giesserei-Zeitung, 1928, Vol. 25, Oct. 15, pp. 591–595; Nov. 1, pp. 621–628; Nov. 15, pp. 650–655). The development of the French iron and steel industry, and particularly the output of iron and steel castings during and after the war, until the present day is discussed. Statistics on the production of coal, coke, iron, and steel, and on the works producing them, are given; various social questions are examined, and the activities and importance of the Comité des Forges are emphasised. Typical examples of a combined iron and steel works, an electric steel foundry, and a grey iron foundry are described.

The Iron and Metal Industry of Russia in the Years 1917 to 1927. P. I. Jegorow and A. P. Iwanow. (Westnik Ingenerow, 1927, Vol. 13, pp. 471–495; Giesserei-Zeitung, 1928, Vol. 25, May 1, pp. 282–283). An economic review of the iron and steel and non-ferrous industries of Russia; the coke blast-furnaces and charcoal works in the Urals, the increased output in the Kusnetzki district, and the production of special steels and weldless tubes are discussed.

The Iron and Steel Industry of Czechoslovakia. F. Pisek. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 17, pp. 224–226). An outline is given of the iron and steel industry of Czechoslovakia. The chief coal and iron ore deposits are mentioned. The leading blast-furnace works are those of Witkowitz and of Trzhinec in the region of Moravska-Ostrava, and the works of Königshof and Kladno in the region of Nuczice. The largest steelworks are those of Skoda and Witkowitz. The native iron ores are insufficient for the industry, and much ore is imported from Sweden, Austria, and Yugoslavia.

Self-Contained Czech Steelworks. F. Pisek and V. Delport. (Iron Trade Review, 1928, Vol. 83, Aug. 23, pp. 446–449, 482; Aug. 30, pp. 515–518). These two articles comprise an illustrated account of the layout and equipment of the blast-furnace and steel plant at the Witkowitz Works in Czechoslovakia.

The Iron and Steel Industry in China. K. L. Hsueh. (Chinese Economic Journal; Iron and Coal Trades Review, 1928, Vol. 116, June 22, pp. 938–939). Tables are given showing the location of the principal iron ore mines; the kind of ore and its composition; the principal iron and steel works, showing the number of blast-furnaces, their daily capacity, and annual production. Statistics are also included of the production of iron and steel in China during the last few years.

HISTORICAL.

Life of James Beaumont Neilson. T. B. Mackenzie. (West of Scotland Iron and Steel Institute, Glasgow, 1928). The brochure was issued in commemoration of the centenary of the introduction of the hot blast, and gives particulars of the life and work of J. B. Neilson, the inventor of the process.

The Rolling of Iron. J. W. Hall. (Proceedings of the Staffordshire Iron and Steel Institute, 1927–28, Vol. 43, pp. 50–59). The history of the development of rolling-mills and the rolling of iron shapes is briefly sketched.

The Construction and Working of a Wire Rolling-Mill 100 Years Ago. H. Dickmann. (Stahl und Eisen, 1928, Vol. 48, July 26, pp. 1006–1008). The firm, Friedrich Thomée A.G. at Werdohl, Germany, has lately celebrated the centenary of its establishment by publishing a special handbook giving a history of the firm's development since its foundation. The founder was Friedrich M. Thomée, who with two partners purchased a site at Werdohl and engaged F. Goecke to build a wire rolling-mill, which was put into operation on December 15, 1827. The mill was driven by an undershot water-wheel and was geared up from 16 revs. of the wheel to 262 revs. of the rolls. The mill consisted of three stands of rolls in line driven by pinions. A plan of the arrangement is shown, with a full description. In 1838 a reconstruction was made, consisting of the introduction by Thomée of independent roughing rolls. A separate roughing train driven by the same water-wheel, and running at a speed of 80 r.p.m., was arranged in front of the first, which latter was converted into a finishing train only. This is the first instance of the use of independent roughing rolls in a wire mill. Water-power continued to be used until 1852, when a steam-engine was substituted for the water-wheel.

FOUNDRY PRACTICE.

GENERAL FOUNDRY PRACTICE.

Melting Iron in the Cupola. J. E. Hurst. (Foundry, 1928, Vol. 56, Sept. 1, pp. 699–701 ; Sept. 15, pp. 746–749, 759 ; Oct. 1, pp. 793–796 ; Oct. 15, pp. 848–852). A series of articles dealing with cupola practice. The first two instalments are devoted to a description of the origin and development of the cupola and the early history of iron-founding. An historical sketch is also given of the life of John Wilkinson, who is usually credited with the invention of the cupola. Modern types of cupolas are described, and the dimensions of British, American, and French cupolas are tabulated. The hourly melting rates of British and American cupolas are also shown.

The Poumay Cupola. C. Geiger. (Die Giesserei, 1928, Vol. 15, Aug. 17, pp. 816–819). **Cupola Control by Auxiliary Tuyeres.** (Engineering, 1928, Vol. 125, June 15, p. 745). The Poumay cupola described aims at producing CO under the fusion zone and completing the combustion of this gas inside the charge itself. Some of the lower tuyeres in the usual positions have forked openings whereby the air is given a swirling motion as it rises through the cupola. The main feature is the provision of a number of small adjustable tuyeres arranged helically around the cupola and connected to the wind belt by pipes ; the whole of the CO formed under the melting zone is proportionately burnt at the various levels. Cupolas fitted with this system show marked improvements in all directions : coke consumption is reduced, melting time is shortened, the temperature of the tapped metal is as high as before, the sulphur content less, and the carbon monoxide in the cupola gas reduced. In the works where these cupolas are installed, further desulphurisation of the cupola metal is effected with soda ash.

Melting Plant and Appliances in Modern Iron Foundries. J. McLachlan and C. A. Otto. (Iron and Steel Industry, 1928, Vol. 1, June, pp. 275–279 ; July, pp. 319–323 ; Sept., pp. 387–391 ; Vol. 2, Oct., pp. 25–28). The authors deal with the various types of cupola and with continuous casting during the length of a blow, and also discuss the blast volume and the quality of castings. They then consider such matters as charging the cupola, the ratio of metal to fuel, regulating the blast, and the necessity for proper temperature control when tapping. Some special types of cupola, crucible and electric furnaces,

are described. Fans, blowers, and various cupola accessories are next dealt with.

Special Construction and Special Operating Methods of the Cupola. L. Schmid. (Die Giesserei, 1928, Vol. 15, Aug. 10, pp. 781–792). The construction and operation of a " normal " cupola is first described, with notes on two special tuyere arrangements designed to prevent them from being choked by slag. The chemical reactions and their heat values and a thermal balance sheet for an ordinary cupola are discussed. The author then deals with the substitution of coke by fluid, pulverised and other fuels, the diminution of the amount of CO formed, the combustion of the CO by means of secondary air, the heating of the blast, the enrichment of the iron with silicon, manganese, and phosphorus, the desulphurisation of cast iron, and the production of high-duty cast iron ; he describes the processes employed, and gives details of the alterations or additions made to the cupola where these are required by the particular processes used.

Cupola Practice. W. H. Poole. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 38, May 31, pp. 395–398).

Cupola Operations are Changing. (Iron Age, 1928, Vol. 122, July 19, p. 148). Improvements in cupola practice are discussed. The problem of diminishing the formation of carbon monoxide in the reduction zone led to the introduction of a secondary air supply, but without satisfactory results. The method of Corsalli, which consists of drenching the coke with slaked lime, seems to offer some advantages. The introduction of a water-spray is said to have brought about a considerable reduction in coke consumption in the case of cupolas for continuous operation. In the Schuermann cupola part of the combustion gases is taken directly from the combustion and reduction zones and utilised for heating the air-blast. These cupolas permit the use of cheaper grades of metal and effect a saving in coke, but neither of these advantages is sufficiently important as yet to warrant the additional expense of this furnace equipment in small foundries.

Better Iron Obtained with Efficient Cupola Operation. A. J. Meissner. (Foundry, 1928, Vol. 56, June 15, pp. 495–496). It is shown that by efficient operation of cupolas a much superior quality of cast iron is obtained.

Expounds Principles of Successful Cupola Operation. J. W. Bolton. (Foundry, 1928, Vol. 56, Apr. 15, pp. 292–295 ; May 1, pp. 363–367 ; May 15, pp. 387–389). The author presents a number of suggestions for the successful operation of cupolas. A bibliography of literature dealing with cupola practice is included.

Some Experiments on the Reaction 2CO $\rightleftarrows$ C + CO$_2$, with Special Reference to Fuel Economy in Cupola Practice. Y. Fugo and F. C. Thompson. (Foundry Trade Journal, 1928, Vol. 38, June 7, pp. 405–406). There is a marked variation in the reactivity of different foundry cokes, those which lead to a greater formation of carbon dioxide being obviously the more economical. There is no advantage from the present standpoint in reducing the temperature of the escaping gases below 200° C., but at 300° C. the waste due to the unnecessary loss of carbon monoxide is appreciable.

The Heat Economy of the Cupola. D. R. W. Müller. (Giesserei-Zeitung, 1928, Vol. 25, July 15, pp. 425–429 ; Foundry Trade Journal, 1928, Vol. 39, Sept. 27, pp. 229–230). The experiments described were carried out to determine the effect of variations of blast volume with constant charge coke, and of variations of charge coke with constant blast. It is shown that the best possible thermal efficiency could be obtained without upsetting the output and temperature of the iron. The results of excessive charge coke are more detrimental than those of moderate excess or deficiency of air. Only when the charge coke reaches 7 per cent. is there reason to fear that the decrease in charge coke causes losses of iron. No relationship could be found between the strength of the resulting iron and the manner in which the cupola was driven.

Heat Balance of the Cupola. J. F. Figueras. (Paper read before the Spanish Foundry Congress : Foundry Trade Journal, 1928, Vol. 38, May 31, pp. 387–388).

Accurate Temperature Measurements in Cupola Operation. P. Rheinländer. (Die Giesserei, 1928, Vol. 15, Sept. 14, pp. 911–917). The most important methods of measuring temperatures, with particular reference to the taking of the temperature of the iron in the trough, the ladle and the furnace, are described. The measurement of the temperature course of the sinking charge and of the rising gases in the cupola is dealt with. As a means of continuously supervising the operation of a cupola the author recommends the measurement of the temperature of the iron when casting and of the top gases.

The Measurement of the Cupola Air-Blast. (Foundry Trade Journal, 1928, Vol. 39, Sept. 20, pp. 201–202). Various types of instruments for the measurement of air-blast are described.

Methods of Mixing Metal. (Iron and Steel Industry, 1928, Vol. 1, June, pp. 287–288). Some old foundry mixtures of 50 years ago are given, together with more modern ones and some in use at the present day.

Present and Future Problems in Foundry Practice. T. Geilenkirchen. (Die Giesserei, 1928, Vol. 15, Aug. 31, pp. 853–860 ; Sept. 7, pp. 889–899). The author reviews and discusses the commercial, technical, and economic problems which exist or will arise in the foundry.

The Technique of the Casting of Cast Iron. J. Petin. (Die Giesserei, 1928, Vol. 15, pp. 749–757). The author discusses the theory underlying the practical methods employed in the foundry, and points out that the production of wasters is generally to be attributed to faulty technique. He describes experiments carried out to investigate the influence of various factors, such as speed of casting, cross-section of runners, &c. He finally gives attention to various details of moulding practice relating particularly to the shape and arrangement of the runners and risers, and gives examples of good practice.

The Technique of Casting Iron, an Important Source of Economy in the Foundry. F. Dengler. (Giesserei-Zeitung, 1928, Vol. 25, June 1, pp. 338–340).

Continuous Operation in the Foundry. Brieger. (Die Giesserei, 1928, Vol. 15, May 4, pp. 406–411). The author discusses continuous operation in general, and the mechanisation of the foundry. With the aid of diagrams and photographs he describes various layouts by which the production of castings may be speeded up and cheapened : the flasks circulate on mechanical conveyors from the moulding shop to the foundry, and after casting continue their journey to the point where they are shaken out, completing the circuit by returning to the moulding shop ; after shaking out the sand is cleaned and returned to the moulders, also by mechanical means.

Principles of Continuous Production. K. Oesterreicher. (Die Giesserei, 1928, Vol. 15, June 29, pp. 621–626 ; July 27, pp. 728–731). The mechanisation of the foundry is illustrated and discussed. The advisability of keeping the weights of castings, and consequently the sizes of the flasks, as nearly equal as possible in any given circulating system is pointed out ; if the flasks are all of a standard size this increases the ease of handling and the economy of the system. In the second instalment the author deals with the problem of organising a foundry for continuous production.

Developments in Furnace Practice for Production of High-Test Cast Iron. R. Moldenke. (Fuels and Furnaces, 1928, Vol. 6, May, pp. 627–630).

High-Duty Cast Iron. H. Jungbluth. (Die Giesserei, 1928, Vol. 15, May 18, pp. 457–466 ; May 25, pp. 486–493 ; Kruppsche Monatshefte,

1928, Vol. 9, May, pp. 69–92). The improvement of the qualities of cast iron may be brought about : (a) by means of alloying additions ; (b) by the production of a pearlitic matrix ; (c) by the reduction of the amount of the graphite ; (d) by the refinement of the graphite—(i) by rapid cooling, (ii) by superheating, (iii) by jolting ; under these headings the author reviews the literature of the subject which has appeared up to the end of 1927. He gives 143 references.

Review of the Present Methods of Producing High-Duty Cast Iron, and Considerations on Some Furnace Problems. Langenohl. (Die Giesserei, 1928, Vol. 15, June 15, pp. 566–571). The relations between the chemical composition, structural composition, and physical properties of cast iron and their application in various processes for the production of high-duty cast iron are discussed, and some of the problems relating to the furnace are considered.

The Production of High-Duty Cast Iron, its Metallurgical Principles, and the Carrying Out in Practice. B. Osann. (Die Giesserei, 1928, Vol. 15, July 6, pp. 648–655). The author points out that all special iron processes really aim at producing an all-eutectic structure and finely divided graphite. The refinement of the latter is brought about by the suitable adjustment of the carbon and silicon, by superheating the metal, or by jolting. The author discusses the metallurgy of the processes ; he deals at length with the superheating process, and asks whether the same result cannot be obtained less expensively. His answer in the affirmative turns on the difference between solid solution carbon and kish. Hanemann attributes the presence of coarse graphite to the precipitation of carbon on nuclei ; the author considers these nuclei to be the kish, which in the ordinary melting of pig iron is not removed and remains in the metal when it is cast. The kish is removed, however, in the superheating process, not by virtue of the high temperature according to the author, but because the longer time permits it to burn off or be removed in the slag ; in the jolting process it is removed mechanically to the surface, where it meets the slag. The raw material requirements, then, for a high-duty iron are a kish-free metal of eutectic composition, and from this point of view the coke and charcoal blast-furnace and the pig-mixer are examined ; charcoal pig may be obtained of suitable quality, but coke pig must be passed through a mixer. Furnaces for melting cast iron are discussed ; the author is an advocate of reverberatories or of electric furnaces for use in the foundry.

Manufacture of High-Grade Cast Iron. M. Girardet. (Bulletin de la Société Industrielle de l'Est, 1928, No. 188, pp. 5–23). The manufacture of high-grade cast iron in the cupola is discussed. Particulars are included of the Dechesne shaking hearth for the desulphurisation of cast iron, and a gyratory hearth designed by the author.

Reviews Progress in Cast-Iron Metallurgy. R. Moldenke. (Paper read before the Spanish Foundry Congress, Apr. 1928 : Foundry, 1928, Vol. 56, June 1, pp. 447–449, 459). A review of recent developments in the production of cast iron.

Cast Iron is Improving. E. Bremer. (Foundry, 1928, Vol. 56, July 1, pp. 541–543, 545 ; July 15, pp. 569–570 ; Aug. 1, pp. 625–626). A discussion of the advances that have been made in the production of high-quality cast iron.

Advancements in Cast Iron Quality show Definite Progress. E. E. Marbaker. (Foundry, 1928, Vol. 56, Aug. 1, pp. 613–615 ; Aug. 15, pp. 657–660). The author reviews the various processes that have been developed in Germany for the production of pearlitic cast iron.

British Refined Pig Irons. (Metallurgist, 1928, Oct. 26, pp. 150–151). The history of the process of refining iron is sketched, with brief details of the methods employed, leading up to modern processes of manufacturing high-duty cast irons.

The Electric Low-Shaft Furnace in the Iron Foundry. H. K. von Scheele. (Giesserei-Zeitung, 1928, Vol. 25, June 1, pp. 341–342). The author first discusses electric furnaces in the foundry in general ; he then deals with the electric low-shaft furnace as a producer of synthetic pig iron, and its advantages over the arched type of furnace. Finally he considers the duplex process employing a low-shaft furnace in conjunction with an arched furnace.

The Heating and Ventilation of a Grey Iron Foundry. A. F. Hager. (Die Giesserei, 1928, Vol. 15, Oct. 12, pp. 1027–1029). The author discusses the disadvantages of the ordinary systems of heating by means of hot water or steam-fed radiators, and describes an installation in an Austrian foundry in which heated air is delivered into the works at various points (*calorifère*). In the summer the furnace is disconnected and cold water is used to cool the air before it is circulated into the foundry.

A New Casting Device. M. Bernardy. (Die Giesserei, 1928, Vol. 15, Sept. 14, pp. 925–927). The device described is intended to assist in transporting the ladle of metal and also in pouring it into the moulds. A light two-wheeled trolley runs on a stout overhead wire stretched throughout the length of the foundry. Hanging from it is a double framework of bars connected together by powerful springs ; the ladle carrier is attached to the lower end of the double framework. The tension in the springs is adjusted to equal approximately the weight of metal in the ladle. The moulds are arranged step-fashion with their runners left free ; the ladle is run along on the wire, and casting is

commenced with the lowest mould. As the ladle becomes lighter, due to the pouring out of the metal, the springs expand and lift the ladle, so that no difficulty on account of weight is experienced in casting the upper moulds.

The Application of the Electric Truck to Material Handling in the Foundry. H. J. Dorus and C. S. Schroeder. (Paper read before the American Foundrymen's Association, May 1928). The authors discuss briefly the operation of electric trucks for handling materials in small foundries.

Material Handling and its Relationship to Building Plans. E. F. Scott. (Paper read before the American Foundrymen's Association, May 1928). The author points out the necessity of proper layout for material handling in relation to building plans of foundries.

Cleaning Room Progress aids Production of Quality Castings. F. G. Steinebach. (Foundry, 1928, Vol. 56, May 15, pp. 401–405; June 15, pp. 481–484; July 1, pp. 546 548, 554; July 15, pp. 593–596, 603; Aug. 1, pp. 636–637; Aug. 15, pp. 680 681; Sept. 1, pp. 725–727; Sept. 15, pp. 768–769, 771). The continuation of a series of articles describing various types of equipment and methods used for the cleaning of castings (*see* Journ. I. and S.I., 1928, No. I. p. 793).

The Rumbling of Castings. H. C. J. Carrington. (Foundry Trade Journal, 1928, Vol. 39, Sept. 20, p. 211). Particulars are given of a plant of twelve tumbling barrels for cleaning castings, in which special attention has been paid to the removal of dust-laden air.

The Design of Castings. R. Lehmann. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, July 28, pp. 1047–1050). The author discusses correct and incorrect designs of castings and other points which the designer should bear in mind.

Gates and Risers for Good Castings. P. R. Ramp. (Iron Age, 1928, Vol. 122, Oct. 18, pp. 943–947; Nov. 1, pp. 1082–1084; Nov. 15, pp. 1218–1220). The author describes and illustrates the correct methods of preparing gates for moulds for face plates, die blocks, cast-teeth gears, driving-box shoes, globe valves, and other castings. If the gates are too large the pouring gate cannot be kept filled during pouring, and thus impurities will enter the mould. The flow of metal should be retarded somewhere between the ladle and the mould. The skim gate should be designed to choke the metal where it enters the inlet gates that lead to the mould, and at the same time provide a free escape for all the impurities collected at this point. The use of pencil gates for thin castings and equalising gates for intricate castings is also discussed.

Methods of Running and Rising Repetition Castings in Steel-Mix Cast Irons. A. Smith. (Foundry Trade Journal, 1928, Vol. 39, July 19, pp. 41–43). The types of runners, risers, and feeding-heads suitable for castings produced from a mixture containing a fairly high percentage of steel are illustrated and described.

Risers : Their Need and Feed. R. R. Clarke. (Paper read before the American Foundrymen's Association, May 1928). The author discusses the conditions governing the use of risers for the feeding of castings, and outlines a suitable method of constructing a feeding riser.

Runners. J. Ellis. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Nov. 1, pp. 322–323). The design of runners for castings is discussed, and several designs are illustrated.

MOULDS AND CORES.

Design and Patternmaking in Relation to Efficient Production of Castings. J. R. Wilson. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Nov. 15, pp. 355–356).

The Tabor Machines. U. Lohse. (Die Giesserei, 1928, Vol. 15, May 25, pp. 481–486 ; June 1, pp. 516–523). A description of various forms of jolting machines manufactured by the Tabor Manufacturing Co., Philadelphia, U.S.A.

Sand-Slinging Machines. Graue. (Giesserei-Zeitung, 1928, Vol. 25, Mar. 15, pp. 181–187). The development of the sand-slinging machine is reviewed, and constructional details of various machines are described.

Core-Making. O. W. Potter. (Foundry, 1928, Vol. 56, Aug. 1, pp. 616–619). A discussion of the factors involved in the production of cores. The clean sharp sand with uniform rounded grains is the most satisfactory kind for use. The action and characteristics of various binders are described, and baking temperatures and typical mixtures are given.

Calculation of the Strengths for the Walls of Moulding Flasks and Core Plates. E. Schneider. (Giesserei-Zeitung, 1928, Vol. 25, Aug. 15, pp. 473–476).

The Arrangement of a Core-Shop for Medium and Small Cores.
E. Springorum. (Giesserei-Zeitung, 1928, Vol. 25, June 15, pp. 361–365). The layout of a core-shop and the installation of core-moulding machines are discussed.

Vertical and Overhead Core Ovens. R. A. Fiske. (Iron Age, 1928, Vol. 121, May 31, pp. 1523–1526). The core-oven installation at the foundry of Nash Motors Co., Kenosha, Wisconsin, is described and illustrated. Owing to the limited floor space available, vertical and overhead core ovens are in use. Continuous conveyors carry the cores through the ovens.

Electrical Heating of Foundry Drying Ovens. E. Diepschlag. (Die Giesserei, 1928, Vol. 15, July 20, pp. 699–703). The manner of the transfer of the heat from the wires of the heating elements to the air in the oven is discussed, and its amounts under various circumstances are tabulated. The economics of the subject are also dealt with.

The Economical Heating of Foundry Drying Ovens. H. Hugo. (Die Giesserei, 1928, Vol. 15, Aug. 17, pp. 819–821). The Voith heater is described. It consists of a refractory-lined cylindrical coke furnace, round which an annular space is enclosed by a second sheet-iron cylinder. A fan drives air into the hot annular space, from which the heated air escapes through an injector placed in the flue of the furnace. The issuing air draws up the fire and completes the combustion of the gases before they enter into the drying oven proper. For an oven of 200 cu. m. capacity about 400 kg. of coke are required for one charge. The furnace is charged with coke and the fan started ; after about 7 hr. the coke has burnt away, so the fan is stopped, but the drying oven is sufficiently hot (about 400° C.) to require no further heating, and when it is opened some 6 or 7 hr. later the moulds are still at a temperature of about 200° C.

Mode of Operation of Foundry Drying Ovens. W. Mann. (Die Giesserei, 1928, Vol. 15, June 22, pp. 591–595). The author discusses the flow of gases through drying ovens, and gives consideration to the theory of Grum-Grimailo, the experiments of that investigator and of Debar, and their application to drying ovens. He discusses the drying process as a heat transference, the possibility of saturating the waste gases with water vapour, and the relationships between the heat transference, heat carriers, moisture carriers, and the thermal conductivity of the moulds with direct and indirect heating.

MOULDING SANDS.

Sand Control Methods and their Developments in a Light Casting Foundry. W. G. Reichert. (Paper read before the American Foundrymen's Association, May 1928). The author discusses the practical application of standard methods of sand testing to the control of moulding sand in a foundry producing light castings.

Sand Control and Sand Conservation in a Grey Iron Jobbing Foundry. T. F. Kiley. (Paper read before the American Foundrymen's Association, May 1928). The author deals with the testing and reclamation of sand as carried out at the foundries of the Brown and Sharpe Manufacturing Co.

The Necessary Condition of Compactness of Moulds ready for Casting, its Calculation and Proof by Means of New Methods. A. Rodehüser. (Die Giesserei, 1928, Vol. 15, Aug. 24, pp. 829–835). The author discusses the mechanical properties of moulding sands and the requirements of a properly rammed mould. He describes a new apparatus for testing the degree of compactness : a weight is permitted to fall vertically on to the sand from a predetermined height measured on a vertical scale ; the distance to which the weight becomes embedded is read off on a vernier attached to it. Results obtained with this apparatus enable a determination of the required compactness to be made, and are at the same time a measure for the apparent density, gas permeability, bonding strength, and porosity of the mould, for with constant composition of the sand the mechanical properties of the sand are functions of its resistance to compression.

Testing Moulding Sands for Durability. M. A. Blakey. (Paper read before the American Foundrymen's Association, May 1928). Apparatus and procedure for testing the durability of moulding sands are described, and the results obtained with different types of sands are included.

An Automatic Precision Strength Test for Sand. G. G. Brown and C. C. De Witt. (Paper read before the American Foundrymen's Association, May 1928). The precision method of testing the compressive strength of moulding sands with an accuracy of + or − 1 per cent. is described. The method involves the use of an automatic testing machine which can be readily adapted for making tensile or transverse tests.

The Influence of Ferric Hydrogel in the Bond of Natural Moulding Sands. C. C. De Witt and G. G. Brown. (Paper read before the American Foundrymen's Association, May 1928). Quantitative data

are presented showing the relation of colloidal ferric oxide absorbed by the sand grains and by the clay bonding material to the strength of bond in moulding sand, and the successful preparation of synthetic moulding sand obtained in the course of work done on Michigan sands for the Michigan Geological Survey. The effect of colloidal iron oxide on the bond of moulding sands was determined by analytical methods on natural sands; and by synthetic methods reproducing the bond of natural moulding sand by the proper combination of clean unbonded sand or silica, kaolin, and ferric hydrosol.

The Cause of the Decrease in Bond Strength on Heating Moulding Sands to 600° F. C. C. De Witt and G. G. Brown. (Paper read before the American Foundrymen's Association, May 1928). The loss in strength on heating is evidently due to changes in the clay, either by decomposition of the crystal structure or by changes in surface conditions, and is not due to changes in the sand particles or in the ferric hydrogel.

On the Testing of Moulding Sand. P. Aulich. (Die Giesserei, 1928, Vol. 15, Sept. 21, pp. 937–944). The author describes the examination of moulding sand to determine the clay content and the sizes of the sand particles, and their amounts; the appearance of the sand grains after sieving is shown in micrographs. He next describes the American Foundrymen's Association standard apparatus for determining the gas permeability and the shearing strength of sands, and the Doty machine for evaluating the transverse breaking strength.

Heat Conduction of Moulding Sand. F. Roll. (Die Giesserei, 1928, Vol. 15, Aug. 31, pp. 860–862). The author describes experiments which show the dependence of the thermal conductivity on the water contents, the compactness, and the volume of the pores of the sand; the effect of the water and of the temperature on the specific heat is also demonstrated.

The Cohesibility of Rammed Sand. I. Lamoureux. (Paper read before the Institute of British Foundrymen: Foundry Trade Journal, 1928, Vol. 38, June 21, pp. 445–446).

Contribution to the Knowledge of the Gas Permeability of Moulding Sands. F. Maske and E. Piwowarsky. (Die Giesserei, 1928, Vol. 15, June 15, pp. 559–566). The authors describe experiments in which the volumes of the gases liberated during the making of castings were determined. In preliminary tests the sand to be examined was used to ram up a plug in a cylinder, a tube leading to a manometer being embedded at a given distance from one face; compressed air was forced through the plug and the readings of the manometer and of a gas-measuring device attached to the other end of the cylinder showed

the relationship between the volume of air passed and the pressure at the given depth from the " pressure " side of the plug.   For the casting tests, the plug, together with the manometer tube embedded at the same distance from the inside face, was placed in position and rammed up in the cope ; the manometer readings when the casting was finished enabled the course of the gas evolution and the degree of permeability of the sand, as well as any changes in its value, to be followed.   A thermocouple was also buried in the sand.   The experiments showed that the volume of gas evolved depended on the thickness of the casting, on the casting temperature, on the type of sand, and particularly on the coal dust and water added to the sand.   Comparative permeability tests of the sand by the casting method and in the laboratory were made, and the influence of the water contents of the sand, the preparation of the mould, the addition of marl, quartz sand, and coal dust to the sand, the drying, washing, and dusting of the mould was determined.   The principal feature of the work is the gas volume measurements obtained from actual castings, which enable the evaluation of a moulding sand on an absolute basis to be made.

What must the Practical Man demand of a Moulding Sand ?   M. Teike. (Die Giesserei, 1928, Vol. 15, Sept. 21, pp. 952–954).   The qualities which are required in a satisfactory moulding sand, and the effect on them of the treatment given to the sand, in preparing the moulds, knocking them out, cleaning the sand, &c., are discussed.

The Suitability of Sands for Oil-Cores.   R. Stotz. (Die Giesserei, 1928, Vol. 15, Sept. 21, pp. 948–952).   The requirements of a quartz sand for oil-cores—plasticity, refractoriness, gas permeability, strength, grain-size, chemical composition—are discussed.   The geology of a deposit in Lausitz and the methods employed there of winning the quartz sand are described.

Foundry Facing Sands. (Iron and Steel Industry, 1928, Vol. 1, Sept., pp. 371–372).   The preparation and use of facing sands are described ; a short list of mixtures of facing sand for various classes of work is given.

SPECIAL CASTINGS.

Combined Iron and Steel. J. F. Kayser. (Metallurgist, 1928, May 25, pp. 73–75).   Combined iron and steel—a product designed to give a combination of two dissimilar properties in one article, and produced in the form of bars, strips, &c.—its manufacture, treatment, properties, and uses are described.   It is composed of an oil- or water-

hardening steel and of an iron so low in carbon that it will remain soft after the steel has been hardened. Moulds with a movable partition are used ; the molten steel is usually cast first into one of the compartments, and as soon as the skin has formed the partition is removed and the molten iron poured into the remaining space. The " lump " is next forged after giving the necessary inspection to ensure a perfect junction of the metal ; the " cogged bar " is then allowed to cool, and is inspected again before it is finally hammered or rolled to the required section. The microstructures of the two parts are quite normal at all stages, and show pronounced interpenetration at the joint.

The Manufacture of Drying Cylinders and Rolls for Paper-Making Machines. E. Knoppick. (Giesserei-Zeitung, 1928, Vol. 25, Mar. 15, pp. 188–191). The author discusses the improved qualities of iron demanded for the casting of cylinders and rolls, the effect of the chemical constituents on the properties of the castings, the composition and charges, and the moulding and casting technique.

A Very Large Steel Casting. (Engineer, 1928, Vol. 146, Oct. 19, p. 442). Brief particulars are given of an anvil block weighing about 95 tons cast by Messrs. Cammell, Laird & Co., Ltd., Sheffield. Two 70-ton open-hearth furnaces supplied the 142 tons of metal required ; the analysis was C 0·251, Si 0·207, Mn 0·881, S 0·041, and P 0·040 per cent. A forged plate of armour quality steel was dovetailed into the top surface to take the wear caused by the die block ; the casting forms the anvil block for a friction drop stamp using a 5-ton tup. The block was cast with the working face downwards ; to avoid the use of small cores, all holes were machined out, and no sign of contraction cavities or other defects was discovered.

The Preparation of the Mould for a Connecting Pipe with Two Branches. R. Löwer. (Röhrenindustrie, 1928, Vol. 21, Oct. 25, pp. 436–438). The preparation of the mould and cores is described.

The Preparation of Moulds for Cast Iron Pipe Bends. R. Löwer. (Röhrenindustrie, 1928, Vol. 21, Sept. 13, pp. 369–371). Two ways of preparing the moulds and cores, according to the number of castings to be made, are described.

Practical Application of Science to Motor Cylinder Manufacture. W. West. (Lecture to the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Oct. 25, p. 306).

Cylinder Metal. F. J. Cook. (Foundry Trade Journal, 1928, Vol. 38, May 31, pp. 385–386). A discussion of some of the factors in the production of cylinder iron.

Castings without Greensand Moulds. (Iron Age, 1928, Vol. 122, Aug. 23, pp. 449–451).   Greensand moulds have been entirely eliminated in the production of automobile cylinder block castings at the plant of Dodge Brothers Inc., Detroit.   The moulds are made entirely of dry-sand cores, a rectangular wedge-shaped box taking the place of the flask.   Castings so made are said to be more uniform in dimensions, in metal thickness, and in weight.   The methods of moulding are outlined.

The Moulding of Bath Tubs by the Jar Ramming Method.   (Foundry Trade Journal, 1928, Vol. 39, Aug. 16, pp. 111–112).

The Manufacture of a Large Surface Plate in Chilled Grey Iron. H. Hugo.   (Die Giesserei, 1928, Vol. 15, June 8, pp. 541–542).

CENTRIFUGAL CASTING.

The Production of Pipes by the Centrifugal Process. C. Pardun. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 11, pp. 1113–1117).   The works of the Vereinigte Stahlwerke, A.G., Abt. Schalker Verein, at Gelsenkirchen, are described.   They were built in 1925 ; each four centrifugal casting machines together with their auxiliary equipment constitute a " group," and two such groups are fed from a common cupola plant.

Improved Process for Casting Pipe Centrifugally in Greensand Moulds. G. Guerrini. (Foundry, 1928, Vol. 56, Oct. 15, pp. 832–835).   Particulars are given of the centrifugal casting process developed by Possenti and Scorza for the production of pipes in greensand moulds. Photomicrographs are given showing the structure of the iron produced by this process as compared with other casting processes.

New Method of Manufacture of Cast-Iron Pipe. M. Von Anacker. (Ingenieria y Construcción, 1928, Vol. 6, Feb., pp. 87–91).   The author gives a general description of the manufacture of cast-iron pipes by centrifugal casting.

Study of Centrifugal Casting. L. Quincy. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, July, pp. 405–410).   A mathematical study of the forces generated by rotating the mould during centrifugal casting, and of the effects of these forces on the molten metal.

A Study of the Centrifugally Cast Pipe (Metal Mould Process) *versus* **Sand-Cast Pipe.** F. N. Menefee and A. E. White. (Paper read before

the American Society for Testing Materials, 1928, Preprint No. 38). The authors describe an investigation to determine the relative merits of centrifugally cast pipe and sand-cast pipe, the scope of the investigation including physical, chemical, and metallurgical tests on 48 specimens of pipe. Of primary importance are variations in thickness, tensile strength, effect of impact, radial compression, and removal of strains.

STEEL FOUNDRY PRACTICE.

Variables in Steel Foundry Practice. F. A. Melmoth. (Paper read before the American Foundrymen's Association, May 1928). A discussion of a number of important factors influencing the production of steel castings : (1) The human element ; (2) the influence of various moulding operations ; (3) the metallurgical behaviour of the steel in the form of a sand-casting ; (4) the heat treatment after casting.

Steel Foundry Practice. P. Longmuir. (Iron and Steel Industry, 1928, Vol. 1, June, pp. 289–290 ; Aug., pp. 357–358). The continuation of a series of articles (*see* Journ. I. and S.I., 1928, No. I. p. 802). In the June instalment the evolution of the basic process is outlined, and the behaviour of phosphorus and sulphur and the action of lime are discussed. In the August instalment the basic Bessemer process is touched upon, and then attention is turned to the basic open-hearth process and the formation of slag.

Electrometallurgy of Steel for Foundry Use. R. J. Richardson. (Iron and Steel of Canada, 1928, Vol. 11, Aug., pp. 232–237). The history of the electric furnace is briefly reviewed and a modern 2-ton furnace is shortly described. Furnace linings, operating practice, &c., are described, and the merits of acid and basic electric steels are compared.

Manganese Steel. H. P. Evans and A. F. Burtt. (Paper read before the American Foundrymen's Association, May 1928). After touching upon the history of the introduction of manganese steel, the authors discuss basic electric melting practice for the production of manganese steel castings. The heat treatment and properties of this material are also discussed.

Make Steel in a Converted Iron Foundry. F. B. Pletcher. (Foundry, 1928, Vol. 56, July 15, pp. 572–575). The methods employed in the manufacture of manganese steel castings at the Burnside plant of the American Manganese Steel Co., Chicago, are described.

The Answers to a Few Questions from the Domain of Steel Casting.
B. Osann. (Die Giesserei, 1928, Vol. 15, May 18, pp. 466–468). By
means of questions and answers the author discusses various matters
which crop up in the steel foundry : the reason why acid steel castings
crack more easily than basic ; why acid steel is used for greensand
castings ; why acid steel burns more violently in the converter ; why
acid steel does not become wild towards the end of a long casting
period ; why it is impossible to add more than 2·9 per cent. of carbon
to molten steel in an electric furnace ; why basic steel toothed wheels
wear more rapidly than acid ; why the carbon can be refined to a
lower figure in basic than in acid steel-making ; what is the difficulty
arising in the use of direct metal in the small converter ; why should
the addition of steel containing nickel and chromium to the cupola metal
for conversion prevent its proper refinement ? is anything likely to
result from American experiments to work a third slag, an aluminous
one, in the basic electric furnace ?

MALLEABLE CAST IRON.

**Graphitisation of White Cast Iron by Annealing below Critical
Temperature.** R. L. Dowdell and J. T. Gow. (Iron Trade Review,
1928, Vol. 83, Sept. 6, pp. 570–571, 578). The authors present the
results of annealing experiments on white cast iron, which show that
graphitisation will proceed on annealing below the lower transformation
point without formation of flake graphite. Graphitisation on anneal-
ing progressed most rapidly in specimens which had been held above
the critical temperature for the greatest length of time (4 hr.) before
the oil-quenching. Microscopic examination of these quenched pieces
failed to show the presence of graphite particles. Small particles of
cementite will decompose on annealing easier than particles of larger
size. The agglomeration of cementite particles on tempering steel of
0·40 per cent. carbon and 0·20 per cent. silicon below the lower critical
point must take place by the diffusion of carbon atoms, with the result
that the small particles of cementite unite in the formation of larger
ones and produce a granular pearlite. In the case of iron alloys of
higher carbon and silicon, such as white cast iron, the carbon atoms,
probably in the presence of gases and metallic oxides, diffuse and
agglomerate about graphite nuclei.

Oxidation Phenomena during the Annealing of Malleable Cast Iron.
H. A. Schwartz. (Paper read before the American Foundrymen's
Association, May 1928). The author attempts to correlate the
researches of Schenck and others with commercial annealing con-
ditions, and outlines what may be expected to happen under various
circumstances as regards compos¡ion of furnace gases and temperatures.

It is shown that the surface metal of malleable castings is strongly influenced by variations in these conditions, and that therefore the machinability of the product may in a large measure be determined by annealing conditions.

Carbon-Silicon Ratio Determines Physical Qualities of Malleable. L. E. Gilmore. (Foundry, 1928, Vol. 56, July 1, pp. 529–531). A brief discussion of the importance of control of carbon and silicon in the production of iron for malleable castings.

Malleable Castings. W. T. Evans and A. E. Peace. (Paper read before the Institution of British Foundrymen : Foundry Trade Journal, 1928, Vol. 38, June 14, pp. 423–426 ; June 21, pp. 454–457 ; June 28, pp. 478–481). The authors present a detailed study of melting and moulding practice for the production of blackheart and whiteheart malleable castings.

Malleable Cast Iron. H. Field. (Proceedings of the Staffordshire Iron and Steel Institute, 1927–28, Vol. 43, pp. 21–39). Heat treatment and chemical composition, the annealing process and defects in manufacture, are discussed.

Malleable Cast Iron. C. H. Plant. (Iron and Steel Industry, 1928, Vol. 1, Sept., pp. 381–383 ; Vol. 2, Oct., pp. 22–24). The author first outlines the development of the process of manufacturing malleable cast iron, and then discusses the annealing process and qualities of iron used. He next discusses the influence of impurities, and the crucible furnace for melting the metal for casting.

On the Contraction and on the Expansion during Annealing of Malleable Iron. F. Henfling. (Die Giesserei, 1928, Vol. 15, June 8, pp. 534–541). Tests on the shrinkage of white iron suitable for making malleable castings revealed that manganese and silicon, though affecting the shrinkage, had very little influence within the commercial limits of composition of malleable cast iron. Runners, gates, the casting temperature, and the fluidity of the metal all had an indirect influence on the shrinkage, due to their effect on the density of the metal. With an exception in the case of flanged bars cast in dry sand, the average shrinkage within commercial limits was assessed at 2 per cent.

Experiments on the expansion of malleable iron during annealing showed that the influence of manganese was small, but that of silicon was great. Sulphur appeared to have a critical point ; below 0·06 per cent. the expansion was high, but above 0·10 per cent. of sulphur the expansion was much less. This difference in sulphur was reflected in the fractures of the bars : the low-sulphur pieces showed blackheart fractures, while the bars with sulphur over 0·10 per cent. had whiteheart fractures. The influence of casting thickness on the

expansion was found to be great in whiteheart annealing, but very small in the blackheart anneal. The course of the change of length during annealing according to both processes was also investigated.

Charge, Melting, and Annealing Costs for High-Duty Malleable Cast Iron. R. Stotz. (Die Giesserei, 1928, Vol. 15, Sept. 14, pp. 905–911).

FOUNDRY PLANT.

Worthington-Simpson Foundry, Newark-on-Trent. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 10, pp. 189–191). The equipment of this foundry is described, including the sand-mixing plant and the stoves used for drying moulds and cores.

New Foundry at the Vulcan Works of Ley's Malleable Casting Company, Ltd. (Foundry Trade Journal, 1928, Vol. 39, Sept. 13, pp. 181–182). A short illustrated account is given of this foundry, which is stated to be the largest of its type in Europe for the production of blackheart malleable castings.

The Iron Foundry of the Siemens and Halske Co., Ltd., at Berlin-Siemensstadt. J. Mehrtens. (Die Giesserei, 1928, Vol. 15, Aug. 10, pp. 794–798). The works are illustrated and described ; notes on the firm's history are given.

The Foundry Industry of Czechoslovakia. F. Pisek (Foundry Trade Journal, 1928, Vol. 39, Aug. 30, pp. 147–152). A general discussion of leading features in foundry practice in Czechoslovakia. A list is given of the larger foundries, and their location is shown by means of a map.

Danish Firm Adopts Novel Idea in Foundry Construction. V. Delport. (Foundry, 1928, Vol. 56, June 15, pp. 497–499, 501). The layout and equipment of the new foundry of Burmeister and Wain, Copenhagen, are described and illustrated. The foundry building is circular in shape, and six travelling cranes pivoted at various heights to a central steel mast can make a complete circuit of the plant.

New Products from an Old Iron Foundry. (Iron Age, 1928, Vol. 122, July 12, pp. 78–80). The new plant of the American Manganese Steel Company, Chicago, is described and illustrated. This plant was formerly a grey iron foundry, but has been equipped for the manufacture of manganese steel castings. The steel is melted in a $1\frac{1}{2}$-ton electric furnace.

The Foundry of the Ford Motor Co. at River Rouge. F. Grützmacher. (Die Giesserei, 1928, Vol. 15, July 13, pp. 679–688). A description of the works with illustrations.

Mechanised Operations Feature Largest Boiler Foundry. E. Bremer. (Foundry, 1928, Vol. 56, Sept. 15, pp. 737–740, 759). An illustrated description is given of the equipment of the various departments of the Bond plant of the American Radiator Co., Buffalo.

How Mechanical Equipment Aids the Stove Foundry Industry. P. Dwyer. (Foundry, 1928, Vol. 56, Apr. 15, pp. 286–291). **Operates Stove Foundry Continuously.** P. Dwyer. (Foundry, 1928, Vol. 56, May 1, pp. 355–359, 367). **Design Patterns for Machine Moulding.** P. Dwyer. (Foundry, 1928, Vol. 56, June 15, pp. 466–470, 474). These three articles form a complete illustrated account of the foundry plant of the Peninsular Stove Co.

Stoves Moulded and Poured Continuously. F. L. Prentiss. (Iron Age, 1928, Vol. 121, May 10, pp. 1310–1316). An illustrated account of the layout and equipment of the new foundry plant of the Peninsular Stove Co., Detroit, for the moulding and casting of stoves.

Effects Savings in Production of Heavy Grey Iron Castings. E. C. Kreutzberg. (Foundry, 1928, Vol. 56, Oct. 15, pp. 842–846, 859). The foundry plant of William Sellers & Co., Philadelphia, is described and illustrated.

Philadelphia Foundry Alloys Grey Iron with Nickel. E. J. Bothwell and F. G. Steinebach. (Foundry, 1928, Vol. 56, May 1, pp. 346–348, 350–351). Moulding practice at the plant of the Cresson-Morris Co., Philadelphia, is described. A variety of heavy and light castings are produced, and nickel is used as an alloying element for certain classes of work.

Pipe Foundry Operates on 24-Hr. Schedule. F. G. Steinebach. (Foundry, 1928, Vol. 56, Aug. 1, pp. 606–612). A detailed account is given of equipment and methods employed at the plant of James B. Clow & Sons, Chicago, for the production of cast-iron pipes.

COOLING PHENOMENA AND DEFECTS IN CASTINGS.

The Shrinkage of Cast Steel. F. Körber and G. Schitzkowski. (Stahl und Eisen, 1928, Vol. 48, Feb. 2, pp. 129–135 ; Feb. 9, pp. 172–178 ; *abstract*, Foundry Trade Journal, 1928, Vol. 39, July 19, pp. 47–48).

Study of Shrinkage in an Iron Casting. M. Servais. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, July 5, pp. 9–10).

Design and Shrinkage. F. C. Edwards. (Foundry Trade Journal, 1928, Vol. 39, Aug. 2, pp. 75–76).

Scabbing. R. F. Coates. (Iron and Steel Industry, 1928, Vol. 1, Aug., pp. 337–338). The cause and prevention of scabbing are discussed.

PRODUCTION OF STEEL.

STEEL-MAKING PROCESSES.

Will Bessemer Production Drop ? G. B. Waterhouse. (Iron Age, 1928, Vol. 122, July 5, pp. 8–11). The author presents a brief survey of the Bessemer steel situation in America. An outline is given of the production of acid Bessemer steel, and it is pointed out that this method of steel manufacture will not only hold its own in the industry, but will improve its position.

The Dependence of the Refining Process in the Thomas Converter on the Course of the Temperature. R. Frerich. (Stahl und Eisen, 1928, Vol. 48, Sept. 6, pp. 1233–1240). A radiation pyrometer was so placed that the course taken by the temperature of the contents of a converter during the blow could be recorded automatically. It was found that in ordinary practice the course of the temperature could vary widely ; after the composition of the pig iron, the factor affecting it most strongly was the blast, which, within limits, is a convenient means of controlling it. The influence of the temperature on the working of the charge, and the most suitable course for the temperature to take to produce the most satisfactory steel and at the same time keep the iron content of the slag at a minimum, were determined.

American Basic Open-Hearth Steelworks. F. Lepersonne. (Revue Universelle des Mines, 1928, Vol. 19, July 1, pp. 5–20 ; Aug. 1, pp. 109–123 ; Vol. 20, Oct. 1, pp. 5–21). Three articles describing the author's observations during a visit to the United States in the summer of 1927. The author first discusses, in a general way, the plant and apparatus used in a typical American steelworks. He next briefly outlines the types and capacities of the furnaces, and then describes fully the general features of American fixed furnaces, concluding with a short section in which the average life of various parts of the furnaces is recorded. Finally he deals with details of the operation of the furnaces, such as composition of the charge, manner of charging, refining, slags, test-bars, deoxidation, recarburisation, teeming, repairs to the furnace, &c.

Improvements in Open-Hearth Furnaces of the Moll Type. K. H. Moll. (Stahl und Eisen, 1928, Vol. 48, Aug. 23, pp. 1160–1165). An illustrated description of improvements in the design of the Moll furnace. In operating a steel furnace it is essential to preheat the air to the maximum degree possible. The preheating of the gas is not

so important, especially with such gases as brown-coal gas or coke-oven gas, on account of the risk of their decomposition, and the gas anyhow generally enters the regenerators at a high initial temperature. Accordingly the air and gas chambers, instead of being built in one block with a party wall, are constructed as two entirely separate chambers placed at different levels. The gas chamber is kept below the furnace port, while the air chamber is raised above the charging platform, the top of the latter being about level with the crown of the furnace, consequently there is no vertical air uptake. Both gas and air chambers are provided with special types of corner stays. At each corner is a vertical cast steel angle, with lugs provided with holes through which pass horizontal stays, so that the entire brickwork is enclosed in a steel cage which prevents buckling of the walls. For the checkers specially designed hollow bricks with oval passage-ways are used.

Open-Hearth Men Discuss Problems. (Iron Age, 1928, Vol. 121, May 10, pp. 1317–1320). **Furnace Operation ; Quality Control.** (Iron Age, 1928, Vol. 121, May 17, pp. 1387–1390). An account is given of the discussions which took place at the Meeting of the Open-Hearth Committee of the American Institute of Mining and Metallurgical Engineers in May last. A number of problems were discussed concerning the construction and operation of open-hearth furnaces.

Effects Observed in Quenched Liquid Steel Pellets and their Bearing on Bath Conditions. J. H. Whiteley. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 57).

Why Tilting Furnaces are Better. C. W. Peirce. (Iron Age, 1928, Vol. 122, Sept. 20, pp. 693–694). The author discusses the superiority of the tilting furnace for the production of steel. According to him better steel at lower cost is made in the tilting furnace. Production of soft and high and raw melting heats can be avoided, faster time per heat can be made, there is less danger of break-outs, and less bottom trouble.

Scientific Principles of the Production of Particular Kinds of Steel. E. Lubojatzky. (Montanistische Rundschau, 1928, Vol. 20, Sept. 1, pp. 517–521). The author discusses the deoxidation and refining processes of steel from the physico-chemical point of view ; he deals mathematically with the partial pressures of the oxides, the relationship between the deoxidiser and the oxygen in the bath, the quantitative elimination of the impurities, and the relative amounts of the protoxides in the bath of steel and in the slag.

Purifying Steel with Sodium Compounds. J. R. Miller. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1204–1205). It is

stated that a special sodium compound developed by C. T. Hennig has been used with excellent results in the manufacture of steel of improved soundness. No particulars are given of the composition of the special mixture, but a brief outline is given showing the method of addition in open-hearth and Bessemer practice, together with micrographs of sections of blooms showing the effect of the mixture in preventing blowholes.

Sponge Iron as a Melting Base. N. K. G. Tholand. (Iron Age, 1928, Vol. 121, May 17, pp. 1391, 1392). The author discusses the use of sponge iron in open-hearth and electric furnace practice. The sponge iron is delivered in pigs about 10 to 11 in. in width and about 2 to $2\frac{1}{2}$ in. thick. The iron content averages about 97 per cent. It is claimed that with the use of this material better steels are produced for the production of seamless tubes, wire, and other products.

Spectropyrometric Measurements in the Siemens-Martin Furnace. H. Schmidt and W. Liesegang. (Mitteilungen aus dem Kaiser-Wilhelm Institut für Eisenforschung, 1928, Vol. 10, No. 5, pp. 71–98). *Abridgment*, **For Purposes of Temperature Measurement, is the Chamber of an Open-Hearth Furnace a Black Body?** H. Schmidt and W. Liesegang. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 677–685). Determinations by previous investigators of temperatures measured with radiation pyrometers in open-hearth furnaces are recorded, and the present trials were made with the object of testing whether the chamber of an open-hearth furnace while in a normal condition of operation can be considered as a black body. The shape, size, structure, and mode of heating of the furnace are discussed in relation to their effect on its black-body condition, and the effect due to the opening of a door is estimated. The spectral course of the absorptive power of freely radiating silica brick was determined. A micropyrometer and its application to the measurement of the absorptive power of basic open-hearth slag and of oxidised iron is described. Optical pyrometers using different colours were employed to determine how far the radiation temperatures measured in the several colours were in agreement. The readings were taken with a Wanner spectral pyrometer on a 50-ton basic furnace with a new lining and with newly packed regenerators, and in the following five spectrum ranges: $\lambda = 0 \cdot 671$ red; $\lambda = 0 \cdot 656$ red; $\lambda = 0 \cdot 579$ yellow; $\lambda = 0 \cdot 546$ green; and $\lambda = 0 \cdot 486$ blue. The observations were made through the peephole of the furnace door nearest the exit ports. The results of all the measurements indicate that the open-hearth cannot be regarded as a black-body radiator. The radiation of the furnace shows dispersion, the differences in the radiation temperatures of the bricks in the blue and red light, within the same temperature range, being about 55°, though less in some cases. The imperfect black-body condition of the furnace chamber makes very difficult the measurement of the hearth

temperature. The highest temperatures recorded in the blue light were 1720° and 1730°. The radiation temperature of the red light was not so high, and it is recommended to take pyrometric measurements in blue light rather than in red light, to avoid risk of fusion of the bricks. The difficulty is the lack of a suitable filter.

Temperature Measurements in the Open-Hearth Furnace. B. M. Larsen. (Fuels and Furnaces, 1928, Vol. 6, Sept., pp. 1163–1168).

Measurement and Calculation of Pressure Losses, particularly in Open-Hearth Furnaces. W. Heil. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 729–740). The losses of pressure in the flow of air and gas through the ports, flues, and checkerwork of open-hearth furnaces are calculated mathematically, and the results are compared with those obtained by actual measurement. For the most part the figures for the actual and the calculated losses differ rather widely. The formulæ used for calculating the frictional resistances were those of Rietschel-Brabbée, with Bansen's modifications for the flues. In open-hearth furnaces of ordinary design the measured losses of pressure worked out at about 100 per cent. below the calculated losses for the ports, uptakes, and checkers, but the measured losses at the air-valve and in the flues to the stack were fully 100 per cent. above the calculated losses. The usual methods for calculating the pressure losses are held therefore to be inaccurate, and the data now put forward supply new factors for use in the design of new furnaces.

Production and Properties of Silicon Steel. C. Wallmann. (Stahl und Eisen, 1928, Vol. 48, June 21, pp. 817–821). Practice in the manufacture and rolling of silicon steel for structural purposes is described. The composition of the steel under consideration was : carbon 0·16, silicon 0·81, manganese 0·82, phosphorus 0·034, sulphur 0·035 per cent. The high silicon content causes the steel to be viscous, so that a high melting temperature is necessary, which entails a rapid wear of the furnace ports, walls, and crown. The life of the ingot moulds is less than half that of the moulds used for ordinary steels. In teeming, a stiff crust forms which is continually being broken up by the stream of molten metal, and is apt to be thrust against the mould walls, causing surface defects on the ingot. In cooling, high-silicon steel pipes very deeply, and in rolling the ingots into plates a discard of 50 to 55 per cent. has generally to be made. The material will roll easily into plates of upwards of $\frac{3}{8}$ in. thick, but the rolling of thin wide plates presents difficulties on account of the increasing toughness of the metal as it cools down. Breakdowns are apt to occur, and if it happens that a thin sheet cools too much to finish safely, it is generally useless for any other purpose and becomes scrap. All these factors tend to raise the cost of production very considerably. To investigate the tensile properties, plates of the thicknesses stated were

rolled from one heat with silicon 0·81 per cent. ; the thicknesses were
9, 12, 14, 20, 25, and 30 mm., and the temperatures at commencement
of rolling were about the same in each case. Longitudinal and trans-
verse test-pieces were cut from the head and foot ends of each plate,
and were tested as rolled and after annealing at 920°. In the as-rolled
state the highest elastic limit was 49·1 kg. per sq. mm. in the 9-mm.
thick plates, and the lowest was 32·1 kg. per sq. mm. in the 25-mm.
plates. In the annealed state the highest elastic limit was 39·8 kg.
per sq. mm. in the 14-mm. plates, and the lowest was 34·1 kg. per sq.
mm. in the 30-mm. plates. The variation in the elastic limit from the
thinnest to the thicker plates was therefore much less in the annealed
than in the unannealed condition. In general, in the annealed con-
dition the yield point ranged from 60 kg. per sq. mm. in the 9-mm.
plates to 55 kg. per sq. mm. in the 30-mm. plates, and the elastic
limit ranged from 38 kg. per sq. mm. in the 9-mm. plates to 35·5 kg.
per sq. mm. in the 30-mm. plates.

Production and Properties of Silicon Steel. H. Koppenberg. (Stahl
und Eisen, 1928, Vol. 48, June 21, pp. 821–822). Extreme care is
required in the manufacture of high-silicon steel, on account of its
tendency to pipe, and in order to avoid cracks, inclusions, and surface
defects. For material from which heavy shapes and thick plates are
to be rolled with a minimum elastic limit of 36 kg. per sq. mm. it is
necessary to allow the carbon to rise somewhat above the low limit of
0·16 per cent., and the steelmaker should be left a free hand in this
respect.

Refine Chrome Steel at Low Heat. N. N. Menshih. (Iron Age,
1928, Vol. 121, June 28, pp. 1817–1818). The author relates his ex-
perience in the manufacture of chromium steel for armour plate at a
basic open-hearth plant in South Russia. He is convinced that when
using scrap containing chromium the amount of chromium remaining
in the refined steel is independent of the amount originally contained
in the scrap, and depends entirely on the method of melting and the
temperature of the bath reached during the refining period. High
temperatures in the refining periods are associated with high residual
chromium, and the quality of the steel is affected very seriously. It
is essential to work the entire heat at a low temperature in order to
obtain a low residual chromium content in the steel.

Production and Inspection of Rails in India. (Iron and Coal Trades
Review, 1928, Vol. 117, July 20, pp. 90–91). Particulars are given of
basic open-hearth and duplex melting practice and rolling-mill practice
for the production of flat bottom rails at the plant of the Tata Iron
and Steel Co. The procedure and methods of inspection adopted are
also dealt with. This information is taken from a pamphlet issued
by the Indian Stores Department and written by E. A. Wraight.

The Manufacture of Steel in India by the Duplex Process.
B. Yaneske. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 4, pp. 281–434).

Uniformity in Duplex Steel. F. W. Sundblad. (Iron Age, 1928, Vol. 121, June 28, pp. 1812–1813). Some of the important points to be observed in operating the duplex process are briefly discussed. Greater uniformity of the finished product is obtained by close control of the temperature of the bath and fluidity of the slag just before the molten pig iron is charged.

Recent Progress in Construction of Electric Furnaces of the Tammann Type. E. Löwenstein. (Chemische Fabrik, 1928, Feb. 15, pp. 77–78). The author describes several types of Tammann furnaces used for the melting of metals.

Brown-Boveri Electric Furnaces with Hydro-Electric Regulation of the Electrodes. E. de Mulinen. (Génie Civil, 1928, Vol. 93, Aug. 11, pp. 143–145). A general description of this type of furnace is given, together with notes on the electrical equipment and illustrations of a 20-ton furnace. The furnace is of the Héroult type ; the electrodes are controlled electrically, but their actual manipulation is carried out by hydraulic means.

Energy Losses in a 7-Ton Héroult Furnace, with Particular Reference to Heat Accumulation Processes. N. Wark. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 145–150). The experiments described were intended to determine the distribution of the energy losses between the transformer, the current leads, the cooling water, the furnace body, and the furnace gases. It was found that the time of charging, the quality of the scrap, and the condition of the furnace refractory walls in particular had an influence on the heat losses of the furnace. The flow of heat through the furnace walls was investigated. It was found that the amount of the accumulated heat decreased during the melting period, as the heat supplied to the walls was insufficient to make up for that radiated externally.

Energy Losses in a 15-Ton Héroult Furnace, with Particular Reference to the Wear of the Roof. H. Klinar, O. Reinhold, and N. Wark. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 151–153). Energy balance-sheets were prepared from the data obtained during four melts using cold charges spaced over the life of one roof ; they showed clearly the dependence of the heat losses on the wear of the roof. With regard to the ability of the roof material to absorb heat, the results obtained confirmed those recorded with a 7-ton furnace (*see* previous abstract). The thermal balance-sheets of melts made with liquid charges showed that the energy supplied was almost entirely

used up in the formation of the slag and in making up the radiation losses.

Determination of the Power Factor of an Arc Furnace. M. Mathieu. (Arts et Métiers, 1928, Vol. 81, July, pp. 266–269). The author describes a graphical method for determining the power factor.

The Regulation of Constant Current Electric Arc Furnaces. M. Mathieu. (Arts et Métiers, 1928, Vol. 81, May, pp. 185–187). The author discusses briefly the mechanism of the correction of current fluctuations, the limiting conditions of the possibility of constant current regulation, and the rapidity of the action of the regulator on an arc furnace.

On Melting and Oxidation Processes in the Basic Electric Furnace. K. von Kerpely. (Giesserei-Zeitung, 1928, Vol. 25, Oct. 1, pp. 568–573). The carrying out and control of the melting process in the electric furnace are considered. The characteristics required in the scrap, the avoidance of disturbing factors, and the course of the melting down, oxidising, and deoxidising periods are discussed.

Electric Steel Manufacture. F. T. Sisco. (Fuels and Furnaces, 1928, Vol. 6, May, pp. 589–600). A general discussion of the types of furnaces and the different processes used in the manufacture of electric steel.

Manufacture of Iron-Carbon-Titanium Alloys in Electric Furnaces. S. Heuland. (Journal du Four Électrique, 1928, Vol. 37, May, pp. 142–144).

Manufacture of Silicon-Manganese Steel in Electric Furnaces. S. Heuland. (Journal du Four Électrique, 1928, Vol. 37, Mar., pp. 78–86).

Making Electric Manganese Steel. J. H. Hruska. (Iron Age, 1928, Vol. 122, Aug. 23, pp. 455–456). The author outlines electric furnace practice for the manufacture of manganese steel. Homogeneous metal, practically negligible losses of manganese, few non-metallic and gaseous inclusions, and the possibility of hotter steel are advantages claimed for making manganese steel in the basic electric furnace. Production costs are higher, however, as compared with open-hearth practice.

Evolution of High-Frequency Induction Furnaces. R. Sevin. (Journal du Four Électrique, 1928, Vol. 37, May, pp. 137–140).

A High-Frequency Furnace with Rotating Spark Gap and Variable Periodicity. M. H. Kraemer. (Stahl und Eisen, 1928, Vol. 48, Aug. 16,

pp. 1120–1124). A 25-kw. high-frequency furnace with a rotating spark gap is described. The electrical oscillations can be varied between 230,000 and 14,000 per sec.; the furnace is therefore capable of dealing efficiently with small charges as well as large, and shows a high concentration of energy in the charge. The cost of the plant is low, and it is simple to build and operate. Brief notes are also given of a 75-kva. Ribaud furnace.

High-Speed, High-Frequency Inductive Heating. E. F. Northrup. (Transactions of the American Electrochemical Society, 1927, Vol. 52, pp. 317–333). A new 300-lb. alloy melting furnace is described, specially designed for melting ferrous alloys. Power is supplied by a 150-kva. generator at 1920 cycles and 900 v.

High-Frequency Heating. (Electrical Review, 1928, Vol. 102, June 1, pp. 943–945). A brief comparative review of the methods of generating the currents necessary for supplying high-frequency furnaces.

High-Frequency Induction Furnaces with Conducting Crucibles. M. Mathieu. (Arts et Métiers, 1928, Vol. 81, Sept., pp. 335–341). The author calculates various electrical characteristics of high-frequency furnaces having crucibles made of conducting materials (graphite, &c.).

High-Frequency Furnaces Operated by Motor-Generators. (Electrical Review, 1928, Vol. 103, July 30, pp. 94–95). The advantages and prospects of the system are reviewed.

The Coreless Type Induction Furnace. N. R. Stansel and E. F. Northrup. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 663–665, 668; July, pp. 787–791, 794). The principles involved in the transfer of energy during the heating of the charge, the part played by the frequency in the attainment of high temperatures and its relation to the allowable heat loss are discussed. The stirring action of the electromagnetic forces on the charge and the ability to melt rapidly are dealt with. The construction of furnaces for various purposes is described.

Progress in the Production of Crucible Steels. (Iron and Steel Industry, 1928, Vol. 1, Aug., pp. 335–336). The possibilities offered by induction heating for the production of crucible steel are shown by means of the results obtained at the Imperial Steelworks, where an Ajax-Northrup furnace is in operation. A table is included showing the comparative qualities of gas-furnace melted high-speed steel and that melted in a high-frequency induction furnace.

Time-Studies as a Means for Obtaining Comparative Data for Estimating the Monthly Production of a Works. H. Steinhaus. (Archiv

für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 55–58). A consideration of the factors which affect the output of a steelworks per month, per shift, and per hour, with a view to establishing a definite relation between the theoretical output and the actual output. The value of making time-studies to serve as a basis for calculating piecerates and for estimating costs of production is emphasised.

Time-Measuring Instruments for Use in Industry. H. Euler and H. Jordan. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 261–282). The article describes and illustrates all kinds of recording instruments, counters, and time-checking clocks for use in iron and steel works.

SLAGS.

Latest Methods of Investigation for the Determination of the Constitution of Slags. O. Glaser. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 73–79; Stahl und Eisen, 1928, Vol. 48, Sept. 27, pp. 1373–1374). Methods applicable to the examination of slags, in particular to the determination of the viscosity, the melting point, the heat capacity, and the change points, are discussed; brief reference is also made to the use of polarised and ultra-violet light to test the stability of blast-furnace slags. The constitutional diagrams of most importance with regard to metallurgical slags, such as the lime-alumina-silica, the manganous or iron oxide-alumina-silica, the calcium or manganese sulphide-silica, and the lime-magnesia-alumina-silica systems, are reviewed. The desulphurisation process in the cupola, the open-hearth, and the electric furnace is discussed in the light of these slag diagrams, and the influence exerted on it by the addition of fluorspar is dealt with.

On the Question of the Citric Acid Solubility of the Phosphoric Acid in Open-Hearth Slags. F. Bernhardt. (Stahl und Eisen, 1928, Vol. 48, Apr. 19, pp. 520–521). Before laying down a new open-hearth plant experiments on the working of liquid basic pig charges by the Bertrand-Thiel and Hoesch processes were made, as these processes depend in part on the production of a high phosphoric slag for their profitable working. It was found that in order to obtain good solubility the slags must be rapidly cooled, and a granulating machine proved quite efficient. Certain Swedish ores containing much phosphorus were used as oxidisers, and it was found that the phosphorus passing from them to the slag was not soluble in citric acid. The most suitable composition for the slag was also investigated, and limits of composition were found to be : FeO 8 to 14, CaO 38 to 44, SiO_2 16 to 20, P_2O_5 16 to 22 per cent. All slags which did not conform to these limits, having either

a too high or too low lime content, possessed a reduced solubility ; the range of the basicity for maximum solubility was from a deficiency of CaO of 2 per cent. to an excess of 4 per cent. For good solubility the phosphorus must exist in the slag as tetra-calcium phosphate, $4CaO.P_2O_5$. The need for rapid cooling of the slag is explained by the fact that on slow cooling this compound loses some free lime, which reduces its solubility. It was also noticed that the appearance of the fracture of a sample varied with the citric acid solubility.

Contribution to the Question of the Citric Acid Solubility and Hardness of Basic Slag. H. Weiss. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 81–85). The dependence of the citric acid solubility on the silica degree is shown diagrammatically. Methods for raising the silica degree, the relation of the silicon content to the phosphorus content in the pig iron, and the action of a sand addition in the converter were investigated. By means of the analyses of about 200 slags with approximately similar silica degrees, it is shown that each 1 per cent. increase in the amount of fine powder increases the citric acid solubility by about 0·33 per cent. ; the economic limit to the degree of fine grinding was investigated. High temperatures of the charge and a low proportion of lime raise the citric acid solubility, whereas rapid cooling decreases it and hardens the slag. Hard slag results especially from high-silicon pig iron, and, besides higher silica and manganese contents, it always contains much ferrous oxide with little ferric oxide. The unfavourable effect of hardness on the solubility is predominantly of a mechanical nature.

On the Citric Acid Solubility of Basic Open-Hearth Slags. P. Kersten. (Revue Universelle des Mines, 1928, Vol. 18, May 15, pp. 167–176). The author discusses the composition of basic open-hearth slags, their preparation and utilisation for manurial purposes.

The Heat Content and the Specific Heat of some Slags at High Temperatures. S. Umino. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 985–996). The author has obtained the heat content and the mean specific heat for a blast-furnace slag and a basic open-hearth slag at temperatures ranging from 100° to 1500° C. by the calorimetric method of mixtures. The slags were found to possess no definite melting point, but to soften and melt gradually in a certain range of temperatures.

Magnetic Control for Modern Slag Plant. W. H. McKay. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1209–1210). The machinery and electrical equipment of the slag-crushing, screening, and loading plant of the France Foundry and Machine Co. are described.

STEEL PLANTS.

Famous British Works. (Iron and Steel Industry, 1928, Vol. 1, June, pp. 281–286 ; Sept., pp. 373–378). The continuation of a series of articles (*see* Journ. I. and S.I., 1928, No. I. p. 821). Illustrated accounts are given of the equipment of the Redcar Works of Dorman, Long & Co., Ltd., and of the Hecla Steel Works of Hadfields, Ltd., with brief particulars of some of the special steels produced at the latter works.

The New Steelworks of the Appleby Iron Company at Scunthorpe (England). (Génie Civil, 1928, Vol. 93, Sept. 1, pp. 201–206). A description, in French, of the works recently described by A. Crooke and T. Thomson (Journ. I. and S.I., 1928, No. I. pp. 171–205).

The Works of Altos Hornos de Vizcaya, Bilbao, Spain. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, pp. 605–606). The equipment of the Baracaldo and Sestao works of this company is described and illustrated.

Enlarging Steel Mill Possibilities. (Iron Age, 1928, Vol. 121, June 7, pp. 1596–1597). Particulars are given of the additions to be made to the steel plant of the Timken Roller Bearing Co., Canton, Ohio. These will include an electric melting furnace, two 100-ton open-hearth furnaces, bar and merchant mills, and auxiliary equipment. The electric furnace will be of the Héroult type, and will be elliptical instead of circular in plan. It will have six electrodes arranged in two groups of three each. The layout of the new rolling-mill plant is shown.

STEELWORKS MACHINERY.

The Water Supply of Steel Mills. (Mechanical Engineering, 1928, Vol. 50, Aug., pp. 621–623). Particulars are given of the water requirements and pumps used in steelworks in three different districts of the United States.

Fettling Machine for Open-Hearth Furnaces. (Iron and Steel Industry, 1928, Vol. 1, July, p. 312). The arrangement of the Blaw-Knox fettling machine is described. The material is fed on to a belt moving at a very high velocity, which is imparted to the dolomite or sand, thereby throwing it into the furnace. Motive power is supplied by a 3-H.P. electric motor, which obtains current through a flexible lead plugged in at any convenient point. The volume of the material and the direction of the stream are controlled by means of a leveAr.

special type of deflector is used when fettling parts that cannot be reached by means of the jet. The machine will throw approximately 1 ton of material per minute.

Lifting Magnets in the Iron and Steel Industries. C. H. S. Tupholme. (Iron and Steel Industry, 1928, Vol. 2, Oct., pp. 11–13). A general article on the types of magnets used in iron and steel works.

Magnet Handles Hot Iron and Steel. F. W. Jessop. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Aug., p. 1077). A brief review of the many applications of lifting magnets to the handling of hot iron and steel.

Handling Problems in the Open-Hearth. J. Richardson. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Oct., pp. 1326-1328). A general discussion of the problems encountered in the handling of materials in and about a steelworks.

Clamshell Buckets in the Steel Industry. E. L. Harrington. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Aug., pp. 1075-1076). A discussion of the structural features required in clamshell buckets to withstand the severe conditions encountered in steelworks. The importance of the weight of the bucket to ensure efficient operation is stressed.

A New Type Ladle Crane. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 650–651). The crane is a 200-ton, 7-motor, 4-girder, ladle crane, with a 40-ton auxiliary trolley. The span is 59 ft. The bridge main (outside) girders support the main trolley, while the auxiliary trolley operates independently on the inner girders, passing under the main trolley. The main hoisting mechanism consists of two interlocked drums driven by two 110-H.P. Crocker Wheeler mill-type motors through two trains of worm and spur gearing. Under normal conditions the motors take equal shares of the load, but provision is made to enable one motor only to take the whole load should the necessity arise.

Heat Losses from a 75-ton Hot Metal Car. W. F. Roeser. (Paper read before the American Foundrymen's Association, May 1928). The author has determined the cooling rate of iron in a closed type of hot metal car, the loss of heat from the surface of the car by radiation and convection and the amount of heat conducted through the lining. Temperature measurements on a 75-ton car with an external surface of 550 sq. ft. (exclusive of opening) showed the heat loss to be $35 \cdot 35$ kg. cal. per sec. This value is the mean of the conduction through the lining ($36 \cdot 41$ kg. cal. per sec.) and the sum of total radiation and convection losses ($34 \cdot 30$ kg. cal. per sec.). In a filled car of the type and

size described the cooling rate of the metal after the first few hours was found to be about 6° C. per hr., which indicates that metal tapped from a blast-furnace at approximately 1500° C. can be held for 40 hr. before freezing. From the data obtained the apparent specific heat of molten pig iron at approximately 1350° C. was calculated to be 0·23.

CASTING AND TREATMENT OF INGOTS.

The Physical Chemistry of Steel-Making ; Deoxidation with Silicon and the Formation of Ferrous-Silicate Inclusions in Steel. C. H. Herty, jun., and G. P. Fitterer. (Bulletin No. 36, Mining and Metallurgical Investigations, Carnegie Institute of Technology, Pittsburgh, 1928). The investigation described in this Bulletin forms a part of a comprehensive study of the physical chemistry of steel-making commenced in 1926 by the Metallurgical Advisory Board in co-operation with the United States Bureau of Mines and the Carnegie Institute of Technology. The Bulletin deals with the deoxidation of steel with silicon and the consequent formation of ferrous silicate inclusions in steel. Part I. is concerned with the equilibrium diagram of the system ferrous oxide-silica and deals with some of the properties of the ferrous silicate slags. Part II. deals with experimental tests in which low-carbon steel was deoxidised with ferro-silicon in varying amounts. It includes a study of the formation of ferrous silicate inclusions, the segregation of the inclusions, the extent of deoxidation, and the importance of fluxing of FeO by ferrous silicate particles. The results obtained are applied to certain phases of steel-making practice. In Part III. the forging of steel containing various types of ferrous silicate inclusions has been studied. The type of inclusions contained varied from pure FeO to almost pure silica. A bibliography of 34 references is appended to the report.

Inclusions in Iron. C. R. Wohrman. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 81–126 ; Aug., pp. 255–299 ; Sept., pp. 385–414 ; Oct., pp. 539–579). The author presents the results of a photomicrographic study of inclusions in iron. Chapter I. is of an introductory nature. The methods used for making artificial known inclusions desired for the studies are described ; the preparation of specimens, in particular the methods of polishing for inclusions, are considered and the technique of microscopic examination is dealt with. The oxide, sulphide, and oxide-sulphide inclusions are described in Chapters II., III., and IV. respectively. Their appearance and typical occurrence is noted as well as their etching characteristics in the more common reagents used in metallographic work. Particular attention is paid to the constitution

of the inclusions and to the much-disputed questions relating to their origin and behaviour. In Chapter V. the evidence thus obtained is summarised and discussed and correlated with accepted theories and hypotheses about the nature of inclusions. The sources of inclusion-forming materials, the status of inclusions in the molten metal and their formation are discussed, and the conditions governing their size, shape, and distribution are outlined. The behaviour of inclusions, their occurrence at grain boundaries, and preferential association with the pro-eutectoid elements are also discussed, and the problem of identification of inclusions is touched upon. The phenomenon of red-shortness receives special attention and a new explanation for it is offered. A bibliography of literature on the subject is appended to the paper.

Investigations into Slag Inclusions in Castings of Small Bessemer Converter Steel with regard to the Casting Process. L. Treuheit. (Die Giesserei, 1928, Vol. 15, June 22, pp. 585–591). The tests described showed that the slag contents of steel from small converters amounted to $0 \cdot 18$ per cent. (Eggertz iodine method of estimation); the lowest value obtained was $0 \cdot 1$ per cent. Test-pieces cast by tipping the ladle contained more slag than those cast through the ladle nozzle. Micro-examination on etched and unetched specimens revealed no sensible difference between the tests cast by the two methods of casting. The nozzle-cast pieces were less inclined to pipe than those poured over the lip of the ladle. The highest slag contents and the choice of casting method had no unfavourable effect on the tensile strength of the steel. On the average the notch toughness values of specimens with more inclusions and cast by tipping were greater than those of the nozzle-cast pieces.

Influence of the Ingot Mould and of Deoxidation on the Crystallisation of Ingots on Solidifying. F. Badenheuer. (Stahl und Eisen, 1928, Vol. 48, May 31, pp. 713–718; June 7, pp. 762–766; *abstract,* Metallurgist, 1928, Aug. 31, pp. 115–116). The influence of the form and design of the ingot mould on the crystallisation of the ingot is discussed. In particular the influence of different thicknesses of the wall of the mould has been studied. The ingots examined were of basic steel with $0 \cdot 13$ to $0 \cdot 34$ per cent. carbon and about 12 cwt. in weight, and were cast both wide-end and narrow-end up. The illustrations show the usual structural features and segregation phenomena.

A Study of Gases Occluded in Molten Steel. E. Ameen and H. Willners. (Jernkontorets Annaler, 1928, Vol. 83, pp. 195–265).

Steel Ingots. (Metallurgist, 1928, June 29, pp. 83–85). An abstract of a paper by F. Beitter and of the discussion raised by it (*see* Journ. I. and S.I., 1928, No. I. p. 824).

FORGING AND ROLLING-MILL PRACTICE.

REHEATING FURNACES.

Reheating Furnaces. F. G. Bell and R. Waddell. (Transactions of the Liverpool Engineering Society, 1928, Vol. 49, pp. 45–66). The authors describe the results of an investigation of reheating furnaces carried out with the objects of reducing the fuel consumption per ton of steel, and reducing or eliminating the emission of black smoke into the atmosphere. For large works where central gas plants are possible there is little to choose between the efficiency of producer-gas fired furnaces and solid fuel furnaces of the latest type. For a small works, or such as cannot install central gas plants, and particularly for the smaller sizes of reheating furnaces, the authors believe the latest type of solid fuel-fired furnaces to be more economical than producer-gas furnaces, and equally smokeless.

Soaking Pit Covers. L. Ellman. (Iron and Steel Engineer, 1928, Vol. 5, May, p. 199). The factors to be taken into account in the design of soaking pit covers are briefly enumerated.

Furnace Requirements for Mass Production. A. J. Stevenson. (Heat Treating and Forging, 1928, Vol. 14, Sept., pp. 1061–1062). The author discusses broadly the innovations introduced into forge and heat-treatment furnaces, and the conditions required in them, in order that the output may be increased without detriment to the quality of the work.

Designs Special Gas-Fired Furnace to Heat Stock for Upsetting. R. C. Gosreau. (Iron Trade Review, 1928, Vol. 82, May 10, pp. 1204–1205). A brief description is given of a gas-fired furnace designed by the author for heating bar stock for upsetting work, together with some operating results.

Ford Uses Many Electric Furnaces. F. L. Faurote. (Iron Age, 1928, Vol. 122, July 12, pp. 73–76). **Electric Forge Furnaces at Fordson Plant.** C. Longenecker. (Heat Treating and Forging, 1928, Vol. 14, Apr., pp. 425–426). The different types of electric forging and heat-treating furnaces in use at the Fordson plant of the Ford Motor Co. are described. Nickel-chromium in ribbon form is used as a resistor

where the temperature does not exceed 1500° F. The Globar type of resistor is used for furnaces operating at higher temperatures.

Standard Units for Forging Furnaces. (Iron Age, 1928, Vol. 122, July 19, pp. 149–150). The International Harvester Co., Chicago, has adopted a standard type of heating furnace for forging work. From a few sizes of bed, side, and end plates, furnaces of varying dimensions are quickly assembled, using tie rod construction and mounting on pipe standards. The gas-burner ports are flat, creating a fan-like sheet of flame.

Gas-Fired Forges at the McCormick Works. J. B. Nealey. (Heat Treating and Forging, 1928, Vol. 14, Aug., pp. 908–909). At the McCormick Works of the International Harvester Co. there are two forge shops ; one devoted to miscellaneous forgings has 125 forges and about the same number of upsetters, bull-dozers, hammers, &c., while the other engaged on bolts and nuts contains 54 forge furnaces and as many hot press bolt headers and nut machines. Details are given of the construction of the furnaces and burners in use.

FORGING, STAMPING, AND DRAWING.

Drop-Forging and Hammer Design. E. C. Clarke. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 619–621). A description of the features in the design of steam drop and board drop hammers that affect the quality and cost of drop-forgings.

Dies and the Board Drop-Hammer. (Heat Treating and Forging, 1928, Vol. 14, Oct., pp. 1172–1175). An outline is given of practice in a modern forge shop.

Forging Manufacture. J. Fearn. (Paper read before the Institution of Production Engineers : Drop Forger, 1928, Vol. 8, Aug., pp. 106–136). Various types of drop-hammers and other forging machines are illustrated and described, special attention being paid to British practice.

Forge Shops of Unusual Flexibility. F. L. Prentiss. (Iron Age, 1928, Vol. 122, Oct. 11, pp. 885–888). The layout and equipment of the forging plant of the Steel Improvement and Forge Co., Cleveland, are described and illustrated.

High-Pressure Water-Tube Boiler Drums. H. Yarrow. (Paper read before the British Association, Sept. 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Sept. 21, p. 408). A short account is given of

the manufacture of hollow forged drums as carried out by John Brown & Co., Ltd., Sheffield.

Forging of a Weldless Hoop. Lebon. (Arts et Métiers, 1928, Vol. 81, Oct., pp. 384–386). The operations employed in forging a weldless hoop, 1·4 m. in diameter, 60 mm. wide, and 25 mm. thick, at the Forges de Combe-Plaine (Rive de Gier), are described and illustrated.

Gear Blanks with Minimum Waste. C. A. McGroder. (Iron Age, 1928, Vol. 122, Oct. 4, pp. 815–817). Particulars are given of the method developed by Dodge Brothers Corporation of manufacturing bevel ring gear blanks. Chrome-vanadium steel bars are fed into a heading machine, where they undergo upsetting and shearing. The upsetting die punches into the centre of the bar and spreads the stock out into a tulip-shaped circular flange, with the more highly refined metal from the surface of the bar on its inside face, where the teeth of the gear will be cut. The rough ring or " doughnut " is sheared from the bar, leaving a deep depression in the centre of the bar which becomes the hole in the next gear blank. After reheating the ring is hammered to the required dimensions and then trimmed. The blank is again hammered to ensure accuracy of shape and dimension.

How Ford Makes Front Axles. F. L. Faurote. (Iron Age, 1928, Vol. 122, Aug. 23, pp. 457–460). The methods of forging and forming, including bending and stretching operations, for the production of front axles for the new type of Ford car are described and illustrated.

The Automobile Drive Shaft. R. L. Rolf. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 72–80). The author briefly outlines in a non-technical manner the manufacture of the automobile drive shaft, touching upon such features as design, forging, machining, testing, physical properties, and materials used. The advantage of using a molybdenum steel to obtain easy machinability with high Brinell hardnesses, thus enabling shafts to be completely machined in the heat-treated state, is pointed out.

Cleaning Forged and Heat-Treated Articles. C. J. Stiers. (Heat Treating and Forging, 1928, Vol. 14, Sept., pp. 1042, 1105). The advantages secured by the application of sand-blasting and tumbling methods to the removal of scale are discussed.

ROLLING-MILL PRACTICE.

The Calculation of the Power Required for the Rolling Process in Relation to the Diameter of the Rolls. L. Weiss. (Zeitschrift für

Metallkunde, 1928, Vol. 20, Aug., pp. 280–282).   By means of mathematical equations and actual rolling tests performed with rolls of various diameters, it is shown that the absorption of power is approximately proportional to the square root of the diameter of the rolls. It is further shown that in a 4-roll mill the saving of power is partly absorbed by the elastic pressing together of the working and the backingup rolls.   The economy of power is explained by the production of a process of drawing at one part of the mill train.   Attention is drawn to the reduced absorption of power by small diameter rolls.

Instruction in the Control of Rolling-Mill Operations.   G. Bulle. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 11–18). The report lays down the main outlines for a practical course of instruction for mill managers and foremen in the working and control of rolling-mills and reheating furnaces.

On the Calibration of Standard Profile (NP) Beams.   F. Torkar. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 155–158). The calibration of roll passes for beams according to Geuze and Kirchberg, the improvements in the latest method, and its applicability to given sections of raw material are discussed.   The passes for rolling an NP 10 beam in 5 and 7 passes are calculated.   Pressures and power requirements are also considered.

Passes for Hot Metal Rolling.   H. A. Slattengren.   (Iron Age, 1928, Vol. 122, July 19, pp. 146–147).   The author discusses the shapes and sizes of various grooves which make up the passes used in hot-rolling, and the relation they bear to each other.   Calculations are made for the reduction of height and of area combined with increasing width of the section produced.

Analysis of Power Consumption Test on a 16-in. Roughing Stand Timken Steel Mill.   F. Waldorf.   (Iron and Steel Engineer, 1928, Vol. 5, Aug., pp. 376–385).   This paper consists mainly of a report compiled by the Timken Roller Bearing Co. of tests on a 16-in. three-high bar mill showing the economy in power consumption effected by the use of roller bearings on the roll necks of the mill.

The Friction Conditions of Bearings under Imperfect Lubricating Conditions.   W. Köhler.   (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 159–168).   The article treats of the frictional conditions of bearings with perfect and imperfect lubrication, and formulæ are given for calculating the friction coefficient, the temperature which the bearing will attain, and the position of the journal within the blocks at different speeds.   The subject is treated mathematically.

The Application of Anti-Friction Bearings to Roll and Pinion Necks. D. M. Petty. (Iron and Steel Engineer, 1928, Vol. 5, Aug , pp. iii–iv, 392). A questionnaire was sent out to various American steel plants in order to ascertain the present status and feeling of the various steel mill engineers concerning the application of anti-friction bearings to roll and pinion necks. Replies to this questionnaire are summarised.

Anti-Friction Bearings for Auxiliaries in the Iron and Steel Industry. E. S. Jefferies. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 242–243).

Anti-Friction Bearings for Electric Motors. J. S. Murray. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 243–248).

Anti-Friction Bearings for Roll Necks. J. H. Van Campen. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 308–310).

Timken Roller Bearings for Steel Mills. F. Waldorf. (Paper read before the Engineers' Society of Western Pennsylvania, Apr. 3, 1928 : Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 611–614). Results are presented of tests carried out on various types of mills fitted with roller bearings. The lubrication and life of bearings are also considered.

On the Question of Rolling-Mill Roller Bearings. F. Braun. (Röhrenindustrie, 1928, Vol. 21, Oct. 25, pp. 433–436). S.K.F. and Timken roller bearings for use in rolling-mills are described, and the results of some tests to determine the power saved are reported.

Symposium on Lubrication. (Iron and Steel Engineer, 1928, Vol. 5, Sept., pp. 391–403). At a symposium on lubrication before the Association of Iron and Steel Electrical Engineers, the three following papers were presented : " Steel Mill Lubrication," by E. P. Mallison ; " High-Pressure Lubrication," by F. D. Street ; " Centrifugal Purification of Oil," by H. T. Moore.

The New Rolling-Mill Plant of the Vereinigte Stahlwerke A.G. at Ruhrort-Meiderich. H. Fey. (Stahl und Eisen, 1928, Vol. 48, June 14, pp. 789–794). These electrically driven mills were put in in 1926, and consist of a cogging mill and finishing mill for billets and slabs. The ingots dealt with are about 5 tons in weight. The reversing cogging rolls are 1150 mm. diam. and 2800 mm. long, with five passes. The capacity of the mill is 3500 tons of ingots per 24 hr. rolled down to blooms of 130 to 400 mm. sq., or slabs 80 × 450 mm. The finishing mill consists of three stands of 3-high rolls 875 mm. diam. and 2250 mm. long. The capacity is 75 to 80 tons per hr. of billets of 50 to 110 mm. sq., or slabs

of 200 × 10 to 40 mm. When working on the heavier sizes the output has reached 100 to 105 tons per hr. The electric equipment is described and the complete plant is illustrated in detail.

Mill Extensions at the Courtybella Works of the Whitehead Iron and Steel Company. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 3, p. 161). The heating furnace is of the Morgan continuous type, designed for heating 30-ft. billets. The roughing mill consists of a continuous train of seven stands of 12-in. horizontal rolls and one stand of vertical edging rolls. The finishing mill consists of four stands of 2-high rolls. The cooling bed is 230 ft. in length and is of the universal saw-tooth type.

The Production of Thin Sheets for Special Purposes. W. Krämer. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 2, pp. 725–733). The author describes the plants and processes employed in the production of thin sheets for special purposes, and discusses the physical and mechanical qualities required. He also deals shortly with specifications.

High-Frequency Coils Between Stands Increase Range of Rolling. L. Cammen. (Iron Trade Review, 1928, Vol. 83, July 26, pp. 194–196). The use of high-frequency coils placed between two stands of a mill for heating sheets or strip between passes is discussed. This method of reheating between passes makes possible the use of the cross-country mill for the production of sheets and strip.

Sheet Steel for Automobile Bodies. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 617–622, 640; June, pp. 770–775; July, pp. 909–913; Aug., pp. 1037–1043; Sept., pp. 1192–1198; Oct., pp. 1313–1318). The continuation of a discussion of the processes involved in the manufacture of sheets for the automobile industry (*see* Journ. I. and S.I., 1928, No. I. p. 840). In the May issue a metallurgical study is given of low-carbon steel used for sheets, including a discussion of critical points and transformations, banded structure, and grain-growth. In the June issue, hot-rolling practice for producing black sheet from sheet bar is discussed. The mechanical features of hot mills, the method of warming up the rolls, the breaking down of the bars, and finishing mill practice, are described. Defects arising in hot-rolling and the influence of hot- and cold-work on the structure and properties of sheet steel are also dealt with. The July article deals with equipment and methods of pickling and cold-rolling sheets. The chemical action in pickling and the physical changes resulting from cold-rolling are discussed. In the August article annealing is discussed, and the equipment and methods used in single box furnaces are described. The September instalment deals with the normalising of sheet steel. In the October instalment the common surface defects which impair the

usefulness of sheets are described, and the causes of faulty surfaces are discussed.

Characteristics of Cold-Rolling Mill Machinery. J. H. Van Campen. (Iron and Steel Engineer, 1928, Vol. 5, July, pp. 326–328). There are two types of mills used for cold-rolling in America. One is the standard 2-high type, which is the most common; the other is the backed-up type employing small working rolls, which are supported by larger rolls. The backed-up type of mill has come very much into favour during the past two years, and will no doubt supersede the 2-high type for heavy duty service. Working rolls used at the present time are mostly of hardened tool steel, heat-treated, ground, and polished. A great number of mills are equipped with anti-friction bearings on the roll necks, and a great saving is effected by their use. The tendency is to work at high rolling speeds; where usually with cold mills for steel the rolling speed was about 100 to 250 ft. per minute, now mills are built for speeds up to 375 ft. per minute. The limit of speed when considering reductions of not less than 12 to 15 per cent. is the ability of the hardened tool steel rolls to stand the strain which is produced from increasing temperature due to rolling. Cold-rolling mills are usually arranged as individual units or in tandem. When arranged in tandem there are usually four stands in such a group, and from such an arrangement the practice is to get anything from 50 to 75 per cent. reduction of the material rolled. For driving the most desirable electrical unit is the d.c. variable speed shunt wound continuous duty motor rated with 40° C. temperature rise.

Construction and Working of Strip-Mills. F. Winterhoff. (Stahl und Eisen, 1928, Vol. 48, July 5, pp. 897–903). The yearly production of strip in Germany has increased from 250,000 tons in 1908 to about 525,000 tons in 1927. The narrowest size with plain edges is about 7 mm. wide, and the widest is limited to about 600 mm. (say 24 in.). For hot-rolled strip the tolerance in thickness is $\pm 0 \cdot 1$ mm. to $\pm 0 \cdot 25$ mm., according to thickness and width. In width a tolerance of ± 1 mm. is allowed for widths up to 80 mm. and ± 2 mm. for widths of 300 to 400 mm. For cold-rolled strip the tolerance in thickness and width is reckoned in hundredths instead of tenths of a millimetre. In hot-rolling it is not possible to go below a certain definite thickness. If the thickness is to be further reduced cold-rolling must be resorted to. Plans of American strip-mills installed in Germany at different dates are shown. Some of the older continuous mills are still working efficiently; one of them erected in 1910 fitted with automatic scale scrapers and planishing rolls has an average output of 70 tons per shift of strip from 70 to 160 mm. wide and 1 to 6 mm. thick. The latest mill is semi-continuous, consisting of eight stands of continuous rolls. After passing these rolls the strip is carried by guide rolls to the main double-duo stand, into which it is automatically guided

through the lower to the upper rolls, being scaled and cleaned at the same time with an air-blast at a pressure of 8 atmospheres. It is then carried by flying guide rolls to the planishing rolls and finished. A bloom of 280 × 75 × 1000 mm. is rolled in 48·5 sec. to a strip 280 × 2·75 mm. The average output of the mill is 120 tons per shift, and it rolls strip of 150 up to 400 mm. wide.

Design and Operation of Strip Mills. (Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1183–1186 ; Oct., pp. 1322–1324). A translation of the above paper by Winterhoff, which formed Report No. 58 of the Rolling-Mill Committee of the Verein deutscher Eisenhüttenleute.

Construction and Working of Strip Mills. C. Schulz. (Stahl und Eisen, 1928, Vol. 48, Aug. 2, pp. 1041–1044). This article describes the strip mills of the firm of Theodor Wupperman. The firm began the rolling of strips and hoops in 1888, and extensions of the plant were made in 1893, 1900, 1914, and 1924. The mill installed in 1914 was a 500-mm. mill with three continuous stands and four double-duo stands. Blooms up to 16 in. wide and $3\frac{1}{2}$ in. thick and billets $4\frac{1}{2}$ in. square, according to required width of strip, were rolled. In 1924 the increased demands for strip led to the instalment of an additional mill, 280 mm. mean diam., consisting of one roughing stand, five stands direct driven, and three continuous stands. The latter are provided with roller bearings, which have run for three years, giving complete satisfaction. They run in dustproof cases, and special care is necessary in roll-changing. The bearings are lifted out bodily with the rolls, and the whole is transported to a separate room where the bearings are fitted on to another roll. The roll journals are fitted in special steel bushes which can be removed when the roll is worn and fitted on to a new one. A sectional drawing shows the whole arrangement. The speed at which the material passes through these rolls is 10 to 12 m. per sec. (32·5 to 39 ft.), and measurements made on strips 300 to 400 m. long have shown that the difference in thickness between the front end and back end is not more than 0·02 to 0·04 mm. ($\frac{1}{650}$ to $\frac{1}{1300}$ in.). The size of strip rolled is 16 to 75 mm. wide, to a minimum thickness of 0·65 mm.

Construction and Working of Strip Mills. H. von Avanzini. (Stahl und Eisen, 1928, Vol. 48, Aug. 9, pp. 1073–1075). The strip mills of the Bochumer Stahl Industrie are described. The mill programme, the sizes of the material for rolling, a furnace with charging and discharging gear, the arrangement of the mill trains and their equipment for rapid rolling, are described ; figures for the output of the plant are given.

Development in High-Speed Strip Rolling. C. E. Davies. (Metal Industry, 1928, Vol. 33, Nov. 2, pp. 413–416).

Rolls Iron Skelp on New Mill. (Iron Trade Review, 1928, Vol. 83, July 12, pp. 75–76, 88). Illustrated particulars are given of the new skelp mill at the Tube Works of the Reading Iron Company, Reading, Pa. The roughing unit includes a single stand of 3-high 16-in. rolls driven by a 500-H.P. a.c. motor. The finishing train comprises three sets of 3-high 12-in. rolls driven by an 800-H.P. a.c. motor. The run-out table, to convey the skelp from the finishing train to the shears, is 140 ft. long and has 42 rollers, each driven by an individual motor. The speed of the rollers is synchronised with the finishing-mill speed.

Location, Number, Capacity, and Range of Pipe Mills in United States by Companies. (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, p. 634). A tabular statement giving the firms' names, the number of furnaces used for making butt-welded or lap-welded pipes, the number of mills engaged on seamless tubes, the diameters produced, and the annual capacity for black, galvanised, seamless, and boiler tubes.

Piercing Billets for Making Tubes. R. C. Stiefel and G. A. Pugh. (Paper read before the American Society of Mechanical Engineers, May 14–17 : Iron Age, 1928, Vol. 121, May 24, pp. 1466–1469). The main portion of the paper is devoted to the plug-mill process for the production of seamless tubes, and a comparison is made between this process and the Pilger process. The advantages of using the smallest possible billets for the production of a given size of tube are pointed out, and the design of the piercing pass, the function of the piercing rolls and piercing mandrel, the power required in piercing, and the expansion of tubes are discussed. Sufficient experimental work has been done to justify the assumption that the expanding method will promote the production of large size tubes up to about 24 in. in diam. from tubes of 14 in. diam. The authors claim that the plug-mill is superior to the Pilger in making seamless tubes. The output is higher, quality of product better, and the equipment and maintenance costs much lower.

The Production of Steel Tubes. E. Röber. (Stahl und Eisen, 1928, Vol. 48, Aug. 16, pp. 1113–1120). The various processes for producing steel tubes are described and illustrated. The largest, smallest, and most usual size of tubes produced by the various processes are tabulated. The processes are compared with one another and their prospects of development discussed.

Investigations concerning the Power Consumption of Skew Rolls and their Economy. W. Moritz. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 741–753). The power consumption of skew rolls for rolling seamless tubes is largely influenced by the form and diameter of the rolls and of the billet. Rolls with a fairly long gently

tapering cone grip the billet better, and the use of a mandrel with a not too sharply tapered point also reduces the power consumption. The billet should enter the rolls with the larger end first, and the speed of the rolls should be slow when first gripping it. The lowest power consumption is obtained when the point of the mandrel is slightly behind the base line of the gripping cones, the most favourable position being given as — 40 mm., and economy in power will result from keeping the mandrel diameter as small as convenient.

British Patents of Seamless Steel Tubing. V. S. Polansky (Blast-Furnace and Steel Plant, 1928, Vol. 16, May, pp. 630–633). A complete list is given of British patents for the manufacture of seamless tubes.

Mill to Roll New Carnegie Beams. G. G. Koon. (Iron Age, 1928, Vol. 121, May 17, pp. 1380–1385). Particulars are given of the new structural mill in operation at the Homestead Works of the Carnegie Steel Co. for the production of H-beams. The mill consists of a 54-in. blooming mill, and 52-in. roughing, intermediate, and finishing stands. The Carnegie beam sections rolled comprise a series of 42 structural shapes in 11 depths ranging from 8 to 30 in. Edging rolls are placed before the roughing stand and following the intermediate stand. The edging rolls are not vertical rolls as the term " edging rolls " customarily indicates. They have horizontal axes, and receive their name from the fact that they work only on the toe or edge of the flanges of the H-beam. They serve also as a feeder into the main rolls, even though they do not effect much reduction. The main rolls do not touch the edges, but do work across the entire face of the web and the inside faces of the flanges. Meanwhile the rolls with vertical axes work on the outside of the flange over its entire width. In plan view these rolls with vertical axes are in line with the main rolls. They lie between the necks of those rolls, but are not driven. Their rotation is imparted by the steel passing through, but they give to it a definite rolling action, nevertheless, through the rigid control over their centre distances. In the intermediate set of rolls this procedure is reversed. The bar by this time has acquired the familiar tongue, so that it may be gripped by the surfaces of the main rolls and pulled through. Here again a set of vertical rolls works on the outside of the flange, while the main rolls work on the inside of the flange and clear across the web. In this set the edging rolls come after the main rolls, and give the necessary amount of work on the edges of the flanges. The finishing rolls are primarily merely a straightening and planishing set, including both horizontal and vertical rolls. They overcome the slight angularity of the relation between web and flange, which is greater in the roughing rolls than in the intermediate, and turn out a finished product in which the respective angles are 90°. Irregular drafting is prevented by automatic roll settings ; and from the time the bloom leaves the shear

until the finished beam is delivered all operations are controlled by four men.

A New Universal Mill for Rolling Wide Flanged Girders, Grooved Rails, Railway Rails, and Universal Bars. H. Hahn. (Stahl und Eisen, 1928, Vol. 48, Aug. 23, pp. 1165–1170). A new rolling mill is described. Its special advantage is its applicability to the rolling of a variety of sections.

Factors Affecting the Economy and Manipulation of Rolling-Mill Engines. G. E. Hider. (Iron and Coal Trades Review, 1928, Vol. 117, Nov. 9, pp. 683–684). Important factors that effect steam economies of rolling-mill engines are tight pistons and valves and reasonable clearances. Several cases in which continuously running engines have been converted to Paxman-Lentz valve gearing are illustrated.

" Step-Back " Control for Steel Mill Drives. (Iron and Steel of Canada, 1928, Vol. 11, July, pp. 218–219). The Canadian General Electric Co.'s relay described in the article is intended to allow the fly-wheel of a slip-ring induction motor-driven mill to take the peak loads, so taking the strain off the motor. In addition to the usual starting resistor and short-circuiting contactors, a second resistor, in two parts, is included in the secondary circuit. Part of this resistor is permanently in circuit, but the other part is normally short-circuited by a contactor. When the load exceeds the value for which the step-back relay is set, it causes this contactor to open, so connecting the additional (or " step-back ") resistor in the circuit ; this produces a sudden decrease in the motor torque, and the stored energy in the flywheel carries the peak load as the motor slows down.

Steel Mill Drives Made Flexible by Speed Control Systems. L. A. Norris. (Iron Trade Review, 1928, Vol. 83, Aug. 9, pp. 321–323, 326). Several types of speed control systems for rolling-mills are compared.

The Overspeeding of Mill Engines. G. E. Hider. (Iron and Coal Trades Review, 1928, Vol. 117, July 20, p. 84). The author describes the momentum type of safety stop gear, and a design of his own for preventing the racing of mill engines.

Yearly Review of Electrical Developments in the Iron and Steel Industry. W. H. Burr. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 211–217). **Electrical Steel Mill Developments.** (Iron Age, 1928, Vol. 121, June 28, pp. 1807–1809). A summary is given of the main roll drives put into operation in America during the past year. In 1920 there were 44 motors driving reversing mills and 113 motors driving other types of mills, making a total of 157 motors on main

roll drives. In January 1928 there were reported over 1500 main roll drive motors in the United States and Canada. Some of the units installed during the past year are of particular interest on account of the methods of control.

Selection of Motors for Main Drives of Merchant Bar and Rod Mills. C. B. Houston. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 218–229). The author describes several types of mills and their drives, and shows how the type of mill and particular layout may materially affect the choice of motor as to type, capacity, speed, and method of control. The author also sketches the early history and development of the different types of mills.

The Selection of Main Drive Motors for Strip and Skelp Mills. A. F. Kenyon. (Iron and Steel Engineer, 1928, Vol. 5, June, pp. 248–255). The factors to be considered in the selection of motor drives for strip and skelp mills are considered

Steel Mill Electric Driving. (Electrical Review, 1928, Vol. 103, Sept. 7, pp. 415–417). Some notes are given of the electrical equipment installed at the works of the Appleby Iron Co.

Constant Speed Electric Motors for Non-Reversing Rolling-Mills. Grivet. (Génie Civil, 1928, Vol. 93, Oct. 27, pp. 405–407). A discussion of the characteristics required in the constant speed electric motors used for driving non-reversing rolling-mills, according to whether they are, or are not, fitted with flywheels. The advantages of dispensing with the flywheel are also discussed.

The Use of Synchronous Motors for Driving Rolling-Mills. W. T. Berkshire and H. A. Winne. (Revue Universelle des Mines, 1928, Vol. 20, Oct. 1, pp. 26–38). This is a French translation of the authors' original paper (*see* Journ. I. and S.I., 1928, No. I. p. 843).

The Driving of Non-Reversing Mills by 3-Phase Motors. Yung. (Paper read before the Société Française des Électriciens, May 1928 : Génie Civil, 1928, Vol. 92, June 23, pp. 613–616). Various arrangements of circuits for controlling 3-phase motors employed for driving non-reversing rolling-mills are described.

Conversion of a 9-in. Guide Mill to Electric Drive. (Iron and Coal Trades Review, 1928, Vol. 117, July 13, p. 50). A short account is given of the electric driving equipment for the 9-in. guide mill at the Netherton Ironworks of Messrs. N. Hingley & Sons, Ltd. The motor is a direct-current compound-wound machine rated at 350 H.P., 200–400 r.p.m., 225 v., the armature weighing $3\frac{1}{4}$ tons.

Electrically Driven Rolling-Mills and Wire-Drawing Plant at Bromford Mills, Erdington. (Iron and Coal Trades Review, 1928, Vol. 116, June 15, p. 895). A brief account is given of the new plant at the Bromford Mills for the manufacture of cast steel wire. Particulars are included of the driving equipment of the rolling-mills.

ROLLING-MILL MACHINERY.

Increasing the Output of a Small Section Rolling-Mill. (Demag News, 1928, Vol. 4, Oct., pp. 92–94). Illustrated particulars are given of a novel type of hot bed roller trough used in a small section mill. It consists of four separate troughs working independently of one another. The bars coming from the rolls each run into a separate trough, and each bar is cut to the predetermined length separately and independently of the others by a shearing machine at the entrance of each trough. The performance of the mill has been increased by at least 60 per cent. since the introduction of the new hot bed trough.

Double Assembly Conveyor for Tube Strip and Band Steel. B. Quast. (Stahl und Eisen, 1928, Vol. 48, May 31, pp. 722–723). In the conveyor described and illustrated the strip is delivered from the mill on to the middle section ; pairs of live rollers are placed so as to drag the material clear of the rolls. The guide plates at the sides, by which the strip is prevented from running off, are lifted, carrying with them the top friction roller of the live roll pair. Levers then push the strip either to right or left, and packs of hot strip are built up in this way. When sufficient strips have collected they are moved by live rollers to the shears which are also fitted with live rollers.

A Thin Sheet Doubler. (Iron and Coal Trades Review, 1928, Vol. 117, Aug. 10, p. 200). An illustrated account is given of the doubling machine designed at the Krupp Gruson works. In this machine the holding-down attachment is so designed that as soon as it is applied it sharply indents the sheet, whereby the position of the fold is definitely secured at the outset so that the sheet cannot shift while the fold is forming. The holding-down and doubling are performed automatically by a crank motion. Hot material may be doubled in thicknesses up to $\frac{1}{8}$ to $\frac{1}{6}$ in.

Double Plate Turn-Over. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, p. 795). A brief description, with illustrations, of the appliance used by the Lukens Steel Co., Coatesville, Pa., for turning over their steel plates during inspection. Movable arms about 5 ft. long and spaced about 5 ft. apart lie in recesses in the aprons of the first inspection table below the tops of the rollers. These arms are

meshed at their pivoted ends with similar arms. The operation of a 20-H.P. motor causes the arms to swing upwards with a scissors-like action, the first set of arms carrying the plates ; the two sets of arms meet with a slight inclination towards the second inspection table, so that when the arms return to their lowered positions the plates are carried down and placed ready for inspection on the reverse side. A second exactly similar set of arms turns the plates right side up again and deposits them on a second roller table ready for removal.

Flexible and Resilient Shaft Couplings. (Engineer, 1928, Vol. 146, July 13, pp. 46–47). The Bibby coupling is illustrated and described. The main feature of this device is the use of a grid-like spring as the flexible and resilient member between the driving and driven sides of the coupling. The spring fits freely in machined flared grooves in the peripheries of the coupling flanges, and acts as a beam loaded at its points of contact with the sides of the grooves. For any given load the stress in the spring is proportional to the span between the points of contact, but the flaring of the grooves is such that the unsupported span is inversely proportional to the load, so that the stress in the spring remains constant over a wide variation in load. The coupling has been applied to over 200 rolling-mills, and a photograph is given of a coupling for a 22,000-H.P. electrically driven cogging-mill at the Central Steelworks, U.S.A. The output of such mills is mainly dependent on the rate at which they can be reversed, and the introduction of this coupling has increased the output of this mill by 40,000 tons per annum. A sketch of a coupling for connecting the leading spindle of a blooming-mill to the reduction gearing of a 20,000-H.P. steam engine is also given ; the impact load on the coupling when stalling occurs as the metal enters the rolls may reach a torque of 2000 ft.-tons.

FURTHER TREATMENT OF IRON AND STEEL.

PYROMETRY.

Note on Practical Pyrometry. G. B. Brook and H. J. Simcox. (Paper read before the Institute of Metals, Oct. 1928). The paper outlines difficulties, such as stray current and magnetic fields of great intensity, which are peculiar to industries where large currents are used. An instrument has been designed which eliminates these and is accurate even when placed in the field surrounding a conductor carrying as much as 20,000 amp.

Chauvin et Arnoux Temperature Regulators. (Aciers Spéciaux, 1928, Vol. 3, Mar., pp. 149–150). This make of regulator is illustrated and described. The pyrometer is connected in the usual way to the galvanometer, which operates relays that actuate the controls of the furnace.

Platinum Thermocouples. (Metallurgist, 1928, July 27, pp. 109–110). English abstract of paper by A. Sourdillon and Rolet (*see* Journ. I. and S.I., 1928, No. I. p. 849).

Measurement of Surface Temperature. D. F. Othmer and H. B. Coats. (Industrial and Engineering Chemistry, 1928, Vol. 20, Feb., pp. 124–126). Methods for attaching thermocouples to heating surfaces by mechanical means may give satisfactory results, but may also give very erratic results. If the junction is formed by plating a layer of the second metal on the surface whose temperature is to be studied, and if the leads are attached before plating so that they are embedded in the plate, uniform results are obtained. Directions are given for making nickel-copper junctions on tubes.

Pyrometers for Surface Temperature Measurements. (Foundry Trade Journal, 1928, Vol. 39, Aug. 2, pp. 79–80). Particulars are given of types of electro-thermic pyrometers suitable for measuring the temperatures of hot metal surfaces.

Thermoelectric Measurement of Temperatures above 1500° C. H. L. Watson and H. Abrams. (Paper read before the American Electrochemical Society, Sept. 1928). After a brief discussion of

the standard methods of temperature measurement from 1000° to 2000° C., an account is given of a tungsten-graphite thermocouple. This couple has been used, with suitable protection, to over 1700° C. in oxidising atmospheres. Repeated runs to 1850° C. have been made in the vacuum furnace, as well as short runs to about 2400° C. at atmospheric pressure in reducing atmospheres.

HEAT-TREATMENT EQUIPMENT.

Developments in Furnaces and Fuel Applications for Them. (Iron Age, 1928, Vol. 122, Sept. 27, pp. 744–749). Various types of heat-treatment furnaces and equipment shown at the National Metal Exposition in Philadelphia are described.

Normalising Sheet Steel. W. Parker. (Iron and Coal Trades Review, 1928, Vol. 117, Sept. 21, pp. 397–398). A new design of furnace for the annealing of steel sheet is described. It is of the continuous type, and the hearth consists of a mechanical conveyor composed of discs by means of which individual sheets or packs consisting of 2, 3, or 4 sheets of thin gauge are transported through the furnace. Both heating and cooling chambers are provided so that the heat treatment may be completely under control during the passage of the sheet through the furnace, which only occupies a few minutes. The heat treatment is carried out in a non-oxidising furnace atmosphere.

Stokers Applied to Annealing Furnaces. J. B. Whitlock. (Blast-Furnace and Steel Plant, 1928, Vol. 16, June, pp. 776–778 ; Heat Treating and Forging, 1928, Vol. 14, May, pp. 539–541). The American Rolling Mill Co., Zanesville, Ohio, has built a series of twelve box-annealing furnaces arranged in six batteries, and has incorporated in them a new stoker developed by the Westinghouse Co. The stoker is essentially a single-retort underfed type as used with boilers, and while certain modifications were necessary to adapt it to the annealing furnaces, its main feature, the unique motion of the grates, was maintained, as this promised results unobtainable with stationary grates. The construction of the furnaces and stokers is illustrated and described. The saving of fuel has proved considerable, and the temperature is both easily controlled and better distributed.

Circular Annealing Furnace Produces Good Results. J. Strauss. (Foundry, 1928, Vol. 56, Apr. 15, pp. 299–300, 303 ; Iron Trade Review, 1928, Vol. 72, May 31, pp. 1406–1408). An illustrated description is given of an oil-fired furnace in operation at the Naval Gun Factory, Washington, for the annealing of castings.

Furnaces for Various Heat Treatments. P. C. Osterman and E. C. Cook. (Heat Treating and Forging, 1928, Vol. 14, July, pp. 781–784 ; Aug., pp. 903–907 ; Sept., pp. 1066-1069, 1086). The first article discusses the treatment of high-speed tool steel, the importance of the correct furnace atmosphere, the necessity for two preheats for all tools and cutters except ordinary lathe tools, and drawing the temper. For the treatment of tool steel oven furnaces and cylindrical furnaces of the vertical type are employed ; the advantages and disadvantages of salt baths are enumerated. The second article deals with gas-fired rotary carburising furnaces, and the third with mechanically operated furnaces.

Modern Conveyor Parts Heat-Treated. J. B. Nealey. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 669 671). Brief notes on the gas-fired furnaces used by the Chain Belt Co., Milwaukee, Wis., for the forging and heat-treatment processes employed in the manufacture of their products are given.

Hardening Cylinder Teeth Automatically. P. H. Waller. (Heat Treating and Forging, 1928, Vol. 14, Apr., pp. 392, 404). The gas-fired furnace is $5 \times 4 \times 45$ in. inside dimensions and is made of brick. Along the bottom is a slot in which travels a conveyor fitted with tooth holders ; teeth are placed in the latter and are carried through the furnace and quenched afterwards. Only the ends of the teeth are hardened, the threads being protected by the holders.

Town Gas and Industry. H. R. Hems. (Paper read before the British Commercial Gas Association, May 9, 1928 : Gas Journal, 1928, Vol. 182, May 16, pp. 451–454). Several installations of gas-fired heat-treatment furnaces are briefly described.

Top-Fired Annealing Furnaces. O. P. Luetscher. (Iron Age, 1928, Vol. 122, July 26, pp. 211–212). The method of firing the annealing furnaces at the plant of the Acme Steel Co., Riverdale, Illinois, is described and illustrated. Raw producer-gas is brought to the furnaces through flues lined with insulating brick. From the main the gas passes through a vertical leg into two valve casings, one at either side and at a level near the crown of the furnace. It is then led into two manifolds and through a series of ports into the furnace chamber. The ports are located below and in line with a series of cast-iron saddles on the lower side of the manifold and resting on the top of the furnace. Immediately above the ports and in line with them another series of saddles resting on top of the manifolds carries the air regulating mechanism. The flame is projected vertically downward.

Special Gas-Fired Furnace Built to Heat-Treat Manganese Steel Castings. O. W. Andersen. (Foundry, 1928, Vol. 56, Aug. 15, pp. 662–665).

Treating Ford Model " A " Parts. F. L. Faurote. (Iron Age, 1928, Vol. 122, July 5, pp. 12–15 ; July 12, pp. 73–77). An illustrated account is given of the plant and practice of the Ford Motor Company for the heat treatment of automobile parts. Both gas-fired and electric furnaces are used for treating ten different types of steel.

Alloy Steel Castings Annealed in Car-Type Electric Furnaces. M. Rock. (Fuels and Furnaces, 1928, Vol. 6, Oct., pp. 1405–1407). Particulars are given of two car-type electric furnaces for heat-treating steel castings.

A Modern Plant for the Heat Treatment of Miscellaneous Steel Castings. A. W. Lorenz. (Paper read before the American Foundrymen's Association, May 1928). The author gives an illustrated account of the furnaces and equipment of the Bucyrus-Erie Co. for the heat treatment of steel castings. The heating equipment consists of four box-type electric furnaces with hearths 5 ft. $\times$ 6½ ft., and one single-chamber car-type electric furnace, with car 3 ft. $\times$ 14 ft.

Furnaces for Continuous Heat Treatment. W. C. Stevens. (Heat Treating and Forging, 1928, Vol. 14, Apr., pp. 423–424). The construction and operation of an electric furnace for hardening small parts for quantity production and uniform results are described.

Dodge Electrifies Heat Treatment. (Iron Age, 1928, Vol. 122, Aug. 16, pp. 389–392). A detailed illustrated account is given of the heat-treating plant of Dodge Brothers, Inc., Detroit, for hardening and tempering motor car parts. The heat-treating furnaces have hearth floors made of 3 alloy plates locked at one end, and an alloy steel wall 10 in. high. The floor is supported by firebrick standing between the heating elements. Heat is transmitted through the floor without much loss, and from ribbons rung on the roof radiating direct.

Precision Heat Treatment for Gears. (Iron Age, 1928, Vol. 122, Sept. 27, pp. 761–764). An illustrated description is given of the methods of heat-treating transmission and ring gears at the plant of Dodge Brothers, Inc., Detroit. Transmission gears are annealed in a double tunnel furnace of the pusher type, heated by electricity. The work moves through the chambers in opposite directions so that the charging end of one tunnel is the discharge end of the other. Operation is automatic and intermittent. The furnace is divided into six zones. First there is a heating zone, then a holding zone, and after that a cooling zone, which is followed by three holding zones. Work in the cooling zone is cooled by forced air delivered by a blower.

Heat-Treating at Dodge Brothers Plant. H. E. Martin. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 525–528). The electric

furnaces and methods employed are described, and the results and costs are discussed.

Advantages of Electric Bath Furnaces. W. C. Stevens. (Heat Treating and Forging, 1928, Vol. 14, July, pp. 785–786, 794). The construction and advantages of bath type electric furnaces are described. Comparisons are made between electrically heated and fuel-fired baths ; the necessity for taking all points into account is emphasised.

Recent Electric Annealing Furnace Installations. K. von Kerpely. (Giesserei-Zeitung, 1928, Vol. 25, June 1, pp. 325-331 ; June 15, pp. 366–374). The author first discusses annealing furnaces in general, dealing with their basic principles, electrical equipment, temperature regulation, &c., and then gives examples of European and American annealing furnaces for various purposes.

Hardening and Tempering by Electricity. (Serial Report of the Industrial Heating Committee, 1926–1927, National Electric Light Association : Heat Treating and Forging, 1928, Vol. 14, Apr., pp. 400–404). Heat treatment and the application of electricity as the heating medium are discussed, and data gathered from existing installations are given for guidance in selecting equipment.

Mechanisation of Electric Annealing and Hardening Furnaces. H. Nathusius. (Stahl und Eisen, 1928, Vol. 48, May 24, pp. 694–697). A furnace with a revolving hearth and automatic discharge into the quenching tank, a tunnel furnace with a roller hearth, and a regenerative case-hardening pusher furnace with four hearths, all electrically heated on the resistance principle, are described and illustrated.

Electric Normalising and Annealing. (Iron Age, 1928, Vol. 122, Oct. 4, pp. 818–821). The different types of electric annealing furnaces in operation at the plant of the Timken Roller Bearing Co., Canton, Ohio, are described and illustrated. There are two 850-kw. pit furnaces for treating steel where the annealing cycle calls for slow cooling. In a well-insulated furnace the cooling time is usually so long that production is seriously delayed. To overcome this, cooling is accelerated in the pit furnaces by means of an air-blast after the critical range is passed. High-carbon chrome steel is normalised in a 700-kw. pusher-type furnace before annealing. Heat treatment of bar or tube stock of alloy steel is accomplished in a 300-kw. hearth-type furnace. Miscellaneous bar stock, especially that which does not require annealing cycles of over 24-hr. duration, or which can be discharged into the open air at high temperatures, is annealed in two car-type furnaces.

Electric Carbon Steel Drawing Oven Uses Forced Air Convection. F. E. Finlayson. (Iron Trade Review, 1928, Vol. 82, June 28, pp. 1667–

1669). Particulars are given of a new electrically heated air-drawing oven. The work is cooled in the heating chamber by means of air circulated by a fan which is driven by a motor mounted externally.

The " Homo " Method of Tempering Steel. (Iron and Coal Trades Review, 1928, Vol. 116, June 1, p. 832). The " Homo " electric furnace, of which particulars are given, is a forced convection furnace. The work is heated by air driven through heating coils by means of a fan.

CEMENTATION AND CASE-HARDENING.

The Gaseous Cementation of Iron and Steel. Part IV.—The Action of Mixtures of Carbon Monoxide and Ammonia on Iron and Steel and its Bearing on the Process of Cementation. A. Bramley and G. Turner. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 23–66). Cementations of Armco iron at various temperatures with mixtures of carbon monoxide and ammonia showed that the carburising action of the mixtures was much greater than that of carbon monoxide alone; this stimulating action was attributed partly to the formation of cyanides, and partly to the influence of the hydrogen formed by the decomposition of the ammonia on the carbon-monoxide/carbon-dioxide equilibrium. The distribution of nitrogen in the cemented zones resembled closely that due to the use of mixtures of carbon monoxide and methyl cyanide, but the mode of distribution of the carbon was more suggestive of the effect produced by pyridine. The carburising power of mixtures of carbon monoxide and hydrogen was greater than that of carbon monoxide alone, but less than that of carbon monoxide and ammonia. The substitution of nitrogen for carbon monoxide in admixture with ammonia caused the production of less nitride. The depth of penetration of carbon at various temperatures was about the same as when carbon monoxide mixed with pyridine and methyl cyanide was used under corresponding conditions. The changes in dimensions of the bars produced by cementation depended on whether the operation was carried out above or below 900° C. They were of the same order of magnitude as those reported in Parts I. to III. (1926, Vol. 15, p. 17; 1927, Vol. 16, p. 35). The micrographs showed that the presence of nitrogen entirely altered the microstructure of the iron-carbon alloys, particularly when cementation occurred below 800° C.; in cementations above that temperature marked segregation of carbide took place. The needles characteristic of steel treated with nitrogenous cements occurred in definite zones, the limitations of which appeared to be controlled by the nitrogen concentration.

The Gaseous Cementation of Iron and Steel. Part V.—Determination of the Iron/Iron-Nitride Eutectoid. The Action of Ammonia on Steels

Containing Different Concentrations of Carbon. A. Bramley and F. W. Haywood. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 67–87). To determine the iron/iron-nitride eutectoid a depth-concentration curve was prepared from one portion of a cemented test-piece, while a composite micrograph of the cross-section was obtained from a second portion. Lines parallel to the surface, and at known distances from it, were drawn on the micrograph, and the total lengths of the line crossing dark areas were measured ; this data in conjunction with the concentration-depth curve enabled the authors to calculate the nitrogen content of the iron/iron-nitride eutectoid to be 2 per cent. ; the eutectoid temperature was deduced as about 608° C. Experiments showed that the amount of nitride formed decreased as the initial concentration of carbide was increased. Slight decarburisation occurred during nitrogenation. Carbon-free nitrogenised steel gave on heat treatment all the structures that are obtainable in the iron/iron-carbide system, but their textures were finer. In an appendix the determination of the iron/iron-carbide eutectoid by the authors' method is described. The values obtained down to a depth of $2 \cdot 0$ mm. agreed very well, and their average was $0 \cdot 892$ per cent. Below $2 \cdot 0$ mm. the values rose rapidly ; the authors assumed this to be due to solubility of carbide in α-iron, and obtained for the solubility of carbon in α-iron an average value of $0 \cdot 04$ per cent.

Facts and Principles Concerning Steel and Heat Treatment.— Part XVIII. H. B. Knowlton. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 127–148). The author deals with solid carburising materials, the methods of packing, carburising protection, the re-use of carburising materials, carburising furnaces, carburising containers, gas carburising, and methods of control of depth of case. The action of the base materials and the chemical energisers in carburising compounds is also explained.

Facts and Principles Concerning Steel and Heat Treatment.— Part XIX. H. B. Knowlton. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 300-315). A discussion of the common errors in case-hardening practice, and methods for their prevention. Cyaniding and nitriding of steel are also briefly discussed.

Facts and Principles Concerning Steel and Heat Treatment.— Part XX. H. B. Knowlton. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 414-434). Heat-treating equipment and methods are discussed.

Facts and Principles Concerning Steel and Heat Treatment.— Part XXI. H. B. Knowlton. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Oct., pp. 580-581). The author

discusses various types of heat-treatment furnaces, the methods of quenching, the regulation of the temperature of the quenching bath, and conveying and handling systems. Some suggestions are made concerning the layout of heat-treating plants.

Important Factors in Case-Hardening. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 500–501). Suitable steels for case-hardening, the carburising compound and its action, and the temperature of carburisation, are discussed.

Carburising Dodge Parts Electrically. (Iron Age, 1928, Vol. 122, Aug. 30, pp. 513–515). Case-hardening practice at the Detroit plant of Dodge Brothers, Inc., is described. Carburising is carried out in special types of furnaces heated with electrical resistors. All parts that are to be quenched from the box are treated in three rotary-type furnaces, and box-cooled parts are carburised in counterflow-type furnaces. Carburising boxes are made of nichrome heat-resisting alloy.

Carburising and Case-Hardening. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 626–629 ; July, pp. 757–761). The effects of various heat treatments of carburised metal on the mechanical properties and structure are briefly noted, and the relative merits of hardening and case-hardening for various purposes are discussed. The factors influencing the process of case-hardening are reviewed, and box carburising and cyaniding are described. Reference is also made to gas carburising and so-called lead-hardening.

Steel for Case-Hardening—Normal and Abnormal Steel. S. Epstein and H. S. Rawdon. (Bureau of Standards Journal of Research, 1928, Vol. 1, Sept., pp. 423–466). That soft spots in case-hardened articles may be due to the kind of steel used has been experimentally confirmed. The characteristics of the so-called normal and abnormal microstructures of the extreme types and intermediate gradations are described. On water-quenching, abnormal steel is more prone to give soft spots. However, on quenching in brine or sodium hydroxide solution, abnormal steel, as well as normal steel, hardens without soft spots. It was found that air or other gases ordinarily dissolved in quenching water may cause soft spots. After carburising, the core of abnormal steel, probably because of its finer grain, shows higher impact strength than the corresponding normal steel. Most cases of abnormality in commercial steel seem to be associated with the use of aluminium for deoxidising, although abnormal steel can be produced in other ways. Nothing arose during the progress of the experiments to controvert Ehn's theory that abnormality is due to dissolved oxides or, more probably, undissolved submicroscopic particles of oxides.

Studies on Normal and Abnormal Carburising Steels. O. E. Harder, L. J. Weber, and T. E. Jerabek. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 961–1008). The authors present the results of experiments and offer certain theories regarding the cause of abnormality in steel, and the mechanism of the formation of the characteristic abnormal structure. The subject is discussed under the following headings: Effect of heating abnormal steels *in vacuo* at carburising temperatures; effect of heating normal steels in nitrogen, oxygen, and carbon dioxide; effect of melting normal and abnormal steels *in vacuo* in alundum and in magnesite crucibles; effect of melting normal steels in atmospheres of nitrogen and carbon monoxide; effect of heating normal steels in contact with "sonims"; X-ray examination, by the powder method, of normal and abnormal steels. The normality of metals deposited by the electric arc under a number of conditions and with some alloy steel welding rods has been investigated briefly; a mechanism is proposed for the formation of the structure found in abnormal carburising steels.

A Note on the Effect of Heat Treatment on Abnormal Case-Carburising Steels. B. M. Larsen and A. W. Sikes. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 355–362). Case-carburising steels may exhibit either grain-size abnormality or structural abnormality. Abnormal grain structures may be changed or modified by various heat treatments in the same way as in other steels. Structural abnormality, which involves a tendency toward the separation of ferrite and cementite in the hypereutectoid zone of the case, is not appreciably affected by heat treatment.

The Addition of Agents for Hardening Metals ; their Composition, Study, and Application. P. W. Döhmer. (Chemiker-Zeitung, 1927, Vol. 51, Sept. 21, pp. 725–726). The ingredients used in manufacturing cementing agents for steel are discussed.

Production Tests of Carburising Compounds. J. S. Ayling. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 1039–1042). The author describes a method of testing the relative merits of various carburising compounds.

The Energising Action of Carbonates Contained in Carburising Mixture. G. Takahashi. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 883–926). The author has studied the effect of carburising agents consisting of mixtures of different carbonates and carbon on the increase of the velocity of carburisation. This action has hitherto been considered as due to the formation of carbon monoxide by the reaction between the carbonate and the solid carbon, but according to the author the acceleration in

the rate of carburisation is due to the liberation of carbon from carbon monoxide, this carbon diffusing into the steel.

The Mechanism of Carbon Penetration in the Cementation of Iron and Steel. G. Takahashi. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 761–782). From the results of experiments the author concludes that the mechanism of the carburisation of iron and steel is not due to the diffusion of carbon monoxide gas, but to the direct diffusion of the nascent carbon atoms produced by the decomposition of the gas.

The Relation Between the Quantity and Depth of Carburisation. G. Takahashi. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 1135–1156). The author has studied the relation between the quantity and depth of carburisation, using several kinds of carburising agents. The tests were carried out for various intervals of time, and at different temperatures. The quantity of diffused carbon was determined by weight increase, and the thickness of the cemented zone by microscopic examination. The results show that the amount and depth of carburisation differ greatly for different carburising agents. For a given depth the amount of carburisation becomes greater with increasing efficiency of the carburising agent. The relation between the amount and the depth of carburisation at a given temperature is expressed by a single parabola. The relation is the same whether the carburising agent is one of the carbon monoxide system or of the hydrocarbon system, provided that carburisation is carried out under the same conditions. At ordinary carburising temperatures, 900° to 1000° C., the influence of temperature and time is small. When the temperature of carburisation is in a range between 900° C. and the A_1 point the carbon density in the innermost layer is the greater the lower the temperature.

Causes of Brittleness in Carburised Parts. S. P. Rockwell. (Heat Treating and Forging, 1928, Vol. 14, Sept., pp. 1026–1028, 1031). The author relates the experiences of a manufacturer of case-hardened motor-car parts and the tests which were made to discover the cause of the failure of carburised parts. In the first place, it was established that the majority of the complaints of failure were received between December and March from Canada and other places where the winters are severe, also that the failures occurred usually in unheated workshops or garages. The tests carried out, which are described very fully, showed what a narrow range of low temperature was sufficient to cause failure.

A Cyanide Flux for Case-Hardening. (Engineering, 1928, Vol. 126, Oct. 12, p. 471). Durferrit is a hardening medium consisting of sodium cyanide as a base with various (unnamed) ingredients added as

accelerators. It is stated that carburisation to a depth of 0·4 mm. can be obtained by treatment for half an hour at 950° C. The flux melts at 500° C. and forms a thin clear melt ; its surface is protected in use by a layer of graphite. The articles after immersion in the molten salt are quenched, annealed at 760° C. for a few minutes, and quenched again. Very few cases of distortion of small parts are said to have occurred during the use of this hardening agent.

Practice of Cyaniding in Heat Treatment. J. W. Urquhart. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 505–506). The use of baths of molten metals or salts for heat-treating objects is discussed. The heating of cyanide baths by means of electricity is touched upon. The passage of an alternating current through the bath itself is feasible but has certain objections ; trials with the use of specially insulated wires or ribbons immersed in the bath are said to be promising.

Cyanide Hardening of Steel. S. Tour. (Fuels and Furnaces, 1928, Vol. 6, July, pp. 883–892). General practice in cyanide hardening is discussed, and reference is made to the Shimer process for case-hardening and the cyanogen gas process.

Carburising with Mixtures of Hydrogen and Natural Gas. W. P. Sykes. (Fuels and Furnaces, 1928, Vol. 6, July, pp. 913–918). For a given concentration of methane in hydrogen, the temperature of heating and consequent diffusion rate of carbon is the most important factor governing the thickness of the case. The results are presented of an investigation of the carburisation of Armco iron by heating in an atmosphere of hydrogen and natural gas, the latter containing about 80 per cent. of methane.

Recent Developments in the Application of Nitrogen to the Surface Hardening of Steel. V. O. Homerberg. (Fuels and Furnaces, 1928, Vol. 6, Sept., pp. 1153–1157). The addition of molybdenum to chrome-aluminium steels completely eliminates the brittleness of these steels due to nitriding. The presence of molybdenum also imparts a greater degree of toughness to the case itself. The nitriding of steel containing chromium, aluminium, and molybdenum is discussed.

The Process of Surface Hardening of Steel by Nitriding. W. J. Merten. (Fuels and Furnaces, 1928, Vol. 6, Oct., pp. 1371–1376). A description is given of the nitriding process and equipment required.

Steels for Case Nitrification. A. B. Kinzel. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 248–254). The author shows the beneficial effect of the presence of vanadium in steel for nitriding. An extremely hard case is obtained with vanadium steel when a minimum of 0·4 per cent. vanadium exists

in solid solution. Satisfactory results were also obtained by treating the surface of plain carbon steel with aluminium or vanadium and then nitriding.

A Note on the Expansion due to Nitration of a Special Alloy Steel. R. H. Hobrock. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 337–342). The author has investigated the expansion of steel specimens due to nitriding. The amount of this expansion is a function of the time of treatment and of the thickness of the case produced. The steel used in the investigation contained carbon $0 \cdot 38$–$0 \cdot 43$, silicon $0 \cdot 20$–$0 \cdot 30$, manganese $0 \cdot 40$–$0 \cdot 60$, chromium $1 \cdot 60$–$1 \cdot 80$, aluminium $1 \cdot 00$–$1 \cdot 25$, molybdenum $0 \cdot 15$–$0 \cdot 25$, and nickel $0 \cdot 30$–$0 \cdot 60$ per cent.

Some Practical Aspects of the Nitriding Process. H. W. McQuaid and W. J. Ketcham. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Nov., pp. 719–743). The authors discuss the nitriding process from a practical point of view, and touch upon the usual method of nitriding, referring to the patents of Machlet and Fry, and the steels suitable for the process. The advantages and disadvantages of the process and the Vickers method of determining the hardness at different depths are dealt with. Curves are given showing the effect of temperature, time, hydrogen concentration, cooling rate, and of reheating on the depth-hardness curve. A microscopical study is made showing the effect of variations of these factors upon the structure. Apparently raising the temperature to about 1200° F. increases greatly the rate of penetration, but reduces the surface hardness. Reheating nitrided pieces to 1550° F. and quenching in water increases considerably the hardness of the nitrided case. According to the authors, the process requires no unusual care in operation, and the results are quite uniform. For general purposes, a temperature of 1200° F. is recommended, although it is found that at 950° F. a harder but much shallower case is obtained.

Nitrogen Hardening. (Kruppsche Monatshefte, 1928, Vol. 9, Jan.–Feb., pp. 23–24). The main features of the production of nitrogenated gear-wheels, &c., are described.

Investigations into the Chemical Corrodibility of Special Steels Treated by the Nitrogen-Hardening Process. O. Hengstenberg. (Kruppsche Monatshefte, 1928, Vol. 9, June–July, pp. 93–96). Tests were made to compare the corrodibilities of plain and alloyed casehardened steels with special steels which had been hardened by the nitrogen process. In one series of tests the specimens were alternately dipped in water and then exposed to the air, and in another series they were surrounded by a mixture of air and steam. The nitrogenated steels evinced a marked resistance to corrosion, particularly

when the silver-grey to blue skin was left on the specimens, while the case-hardened steels were strongly attacked. In a third test the behaviour of nitrogenated special steels towards copper sulphate solution was investigated. Their potential was found to be so " noble " that they remained unattacked. A simple means was devised from this test to determine the depth of the hardened zone.

Nitrogen Process of Surface Hardening. (Metallurgist, 1928, Oct. 26, pp. 154–155). Abstracts are given of the above two articles.

Nitrogen Hardening. (Kruppsche Monatshefte, 1928, Vol. 9, Mar., pp. 46–52). The principal points in the manufacture of nitrogen-hardened parts, such as shafts, crankshafts, connecting rods, slides, links, templates, tools, &c., are described.

HEAT TREATMENT OF IRON AND STEEL.

Principles of the Heat Treatment of Steel. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Oct., pp. 502–538 ; Nov., pp. 744–776). An outline is given of the elementary principles of the heat treatment of carbon steels. The paper has been prepared by the Metallurgical Staff of the Bureau of Standards in as simple terms as possible for the information of those who possess little or no metallurgical knowledge. Definitions of the more important terms are included where considered necessary.

Heat Treatment of Ferrous Metals. C. M. Walter. (Paper read before a Joint Meeting of the Chemical Engineering Group and the Birmingham Section at Birmingham : Heat Treating and Forging, 1928, Vol. 14, Aug., pp. 884 888). A general outline of the theory and practice of the heat treatment of iron and steel, including alloy steel, is given ; fuels and furnaces adapted for these purposes are also dealt with.

Heat Treatment of Steel in the Electric Furnace. (Iron and Steel Industry, 1928, Vol. 1, Aug., pp. 354–356).

Making and Treating Various Steels. L. C. Miller. (Heat Treating and Forging, 1928, Vol. 14, Sept., pp. 1029–1031, 1035). In this discussion of steel-mill practice and of heat-treating practice the author advocates the co-operation of the producer and the manufacturer, as the methods employed in the steel plant are such that the final properties obtained in the manufacturer's works on a certain part may often be controlled or improved appreciably by certain melting or rolling practices.

Notes on the Relation of Design to Heat Treatment. F. R. Palmer. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Oct., pp. 469–476). The paper sets forth the fundamental principles of design of steel parts as they affect heat treatment and serviceability. From the standpoint of heat treatment, a tool or machine part is properly designed when the entire piece may be heated and cooled at approximately the same rate, thus eliminating so far as possible internal strains which develop during quenching. The correct shaping and balancing of the weight of sections is discussed, and examples of good and poor design are presented.

Heating of Steel by the Controlled Temperature Method. G. W. Hegel. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 377–384). The author shows the effect of the rate of heating through the critical range on the temperature distribution in a piece of steel.

On the Distortion of Repeatedly Heated and Cooled Bodies. F. Berger. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 30, pp. 921–926). The increase of length due to heating as a non-reversible process is discussed mathematically. The growth of metals (cast iron, brass) and the influence of the rate of cooling are discussed. The resulting surface stresses are calculated. As an example the results obtained on heating a piece of steel 374 times are given. The temperature distribution on rapid cooling is calculated, and the course of the temperature of individual points in relation to the time is discussed. The author concludes that the thermal expansion and contraction of solid bodies is not a reversible process, except within narrow temperature limits, which depend on the material. If the body be repeatedly taken through the heating cycle the process becomes more and more nearly reversible, the more so as the number of heating cycles is increased and as the limits of temperature are separated. On cooling from temperatures at which it is plastic to those at which it is solid, every body tends to assume the shape of a sphere, the tendency increasing with the rapidity of cooling and with the number of times that it is cooled from the temperature of plasticity to that of solidity.

Distortion Produced by Repeated Heating and Cooling. (Metallurgist, 1928, Oct. 26, pp. 156–157). Abstracts of the preceding article and one by Schwinning and Flössner (*see* Journ. I. and S.I., 1927, No. II. p. 598) are given.

Deformations due to Quenching in Cemented and Quenched Pieces. R. Barat. (Arts et Métiers, 1928, Vol. 81, July, pp. 262–266 ; Revue de Métallurgie, Mémoires, 1928, Vol. 25, Oct., pp. 585–589). The author discusses the changes in dimensions which occur in cemented

pieces during quenching. The subject is dealt with mathematically, and it is shown that the alterations in dimensions which a piece will suffer during quenching may be forecast in advance.

Heat Treatment of Forgings and Castings for Selective Directional Adjustment of Residual Stresses. W. J. Merten. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 193–198). The author discusses selective cooling for the purpose of producing favourable directional internal or residual stresses in forged discs or cast parts of rotating bodies. Ordinary cooling from the periphery toward the centre is conducive to conditions detrimental to the application of the parts and their subjection to centrifugal stresses. The discs are supported on a mandrel over the quenching tank, and a water spray is directed against the centre while the disc is rotated.

Mass Effect in the Heat Treatment of Large Forgings. J. A. Jones. (Metallurgist, 1928, May 25, pp. 70–72 ; June 29, pp. 86 90). The influence of mass in the heat treatment of alloy steels was investigated. A series of tests showed the variation of properties through the thickness of the walls of large hollow forgings. The influence of mass was further demonstrated by the difference in the properties obtained on re-treating a small piece at the same temperatures as were used for the large forging. The marked differences in microstructure associated with the alterations in mechanical properties are discussed. The data show that the lack of uniformity is greatest when the rate of cooling imposed by the mass approximates to the critical rate of cooling for hardening. They show the unsuitability of nickel steel for large forgings and the important effect of molybdenum in suppressing mass effect in Ni–Cr Mo steel. In this steel the reduced rate of cooling of a large mass of metal through the critical range may result in a reduced impact figure, but this is not due to temper-brittleness, as the impact figure obtained is not susceptible to further alteration by varying the cooling rate after tempering.

Effect of Heat Treatment on the Properties of Chromium-Molybdenum Sheet Steel. F. T. Sisco and D. M. Warner. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 177–192). The results are presented of tests on chromium-molybdenum steel sheets of a composition (C 0·25 0·35, Cr 0·80–1·10, Mo 0·15–0·25 per cent.) suitable for aircraft construction. The effects of heat treatment on the physical properties and structure are shown for sheets of several gauges. To secure the best combination of strength and ductility as measured by the ultimate strength, yield point, hardness, elongation, and bend tests, the sheets should be normalised, hardened by quenching in water from 1600° F., and tempered between 1000° and 1200° F. The elongation of this type of steel after heat treatment decreases materially as the gauge becomes thinner. It is shown by

the investigation that for good commercial sheet, rolled according to best practice, test-pieces cut lengthwise or crosswise of the sheet should have the same properties.

Effect of Quenching Temperature Change on the Properties of Quenched Steel.

O. W. McMullan. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Oct., pp. 477–501). A comparison of hardness results obtained by different hardness testers is shown plotted against the Vickers hardness as a standard. Curves showing the hardness obtained on the case and core of carburised nickel-molybdenum steel and plain carbon steel are presented, and the effect of low-temperature tempering is shown. Medium carbon alloy steels and plain carbon steels were treated in different sizes, and the hardness at the surface and the centre was determined. These steels were given both a drastic quench and a mild quench to duplicate commercial conditions. A high-carbon tool steel was also treated. Tensile and impact results were obtained on all but the tool steel. The results show that maximum surface hardness on high-carbon steels is obtained at low quenching temperatures, and that maximum centre hardness of quenched steel occurs at a much higher temperature along with a more or less sudden increase in grain-size. The effect of a tempering treatment at 500° F. on low-carbon steel quenched within the critical range is very pronounced on the hardness, tensile strength, and notch brittleness.

Annealing Tests for the Improvement of Transformer Sheets.

M. von Moos, W. Oertel, and R. Scherer. (Stahl und Eisen, 1928, Vol. 48, Apr. 12, pp. 477–485). Recrystallisation tests on finished transformer sheets rolled from different heats show that, in addition to the carbon content of a sheet, the oxygen content exercises a decisive influence on the magnetic properties of the sheets. Melts were prepared with the following compositions: (1) Carbon 0·04, silicon 0·46, oxygen 0·002–0·01 per cent.; (2) carbon 0·18, silicon 4·38, oxygen 0·053 per cent.; (3) carbon 0·12, silicon 4·13, oxygen 0·041 per cent. Annealings were carried out for different periods, at different temperatures, in packing and in a hydrogen atmosphere. In general, the sheets with high oxygen show a structure that is not uniform or sharply defined. The quality of a transformer sheet depends not only on the absolute size of the crystals, but on their sharpness and uniformity of size. An annealing in a current of hydrogen improves all transformer sheets.

Heat Treatment for Die Blocks.

J. W. Urquhart. (Heat Treating and Forging, 1928, Vol. 14, Aug., pp. 852–855, 862). A report on the heat treatment of die blocks by a Committee of the American Society for Steel Treating is discussed, and a comparison is made of the methods used in England with those standard in America.

The Constitution of Steel and Cast Iron. Section II.—Part IV. F. T. Sisco. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 1043-1057). The author continues his discussion of the changes taking place in annealing, and the relation between these changes and stable or unstable equilibrium.

The Constitution of Steel and Cast Iron. Section II.—Part V. F. T. Sisco. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Nov., pp. 767–779). The slip interference theory of hardening is discussed.

Hardening Cold Heading Dies. L. S. Cope. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 51–60). A quenching apparatus is described which has been successfully used for the quenching of cold heading dies. With this apparatus it is possible to quench a die so that the portion around the hole will be hard to withstand wear, and the remainder of the die will be soft enough to withstand the shock produced by cold heading. The die is heated and then placed in the apparatus, where water at 80-lb. pressure is allowed to pass through the die. When the outside of the die has cooled to a dull red it is completely submerged until fully cooled. A pair of tongs is also described by which header hammers may be quenched so that the ends only will be hardened.

Heat Treatment of Grey Iron. E. E. Marbaker. (Iron Age, 1928, Vol. 122, Aug. 2, pp. 282–285). The best results in normalising strained castings have been obtained by heating at temperatures considerably below the critical temperature for periods of time depending upon the size and section of the castings, the object being to ensure the heating of the castings throughout to the annealing temperature, and then cooling slowly. In order to soften the castings and render them more easily machinable they must be heated at a temperature above the critical point, held for a sufficient time to ensure thorough heating, and then cooled slowly at least through the first 100°. Castings may be hardened again after machining if desired by reheating, quenching, and drawing to the desired hardness.

The Thermal Treatment of Rails in Service. E. Marcotte. (Génie Civil, 1928, Vol. 93, Sept. 8, pp. 232–236). After a brief reference to methods for redressing worn rails, the author describes and discusses the Sandberg *in situ* process of heat-treating rails.

The Use of the Microscope in Heat Treatment. H. M. Boylston. (Fuels and Furnaces, 1928, Vol. 6, Oct., pp. 1377–1382). The author reviews the developments in the microscopic examination of metals. The importance of high-power micrography and its utility in controlling various heat-treating operations are pointed out.

WELDING.

Notes on Welding. F. Töpfl. (Stahl und Eisen, 1928, Vol. 48, July 19, pp. 961 971). A general review of recent progress in gas and electric welding. The apparatus and preparation of parts and surfaces to be welded are illustrated. A new electric cutting apparatus is also illustrated and described.

Welding Ford Rear Axles. F. L. Faurote. (Iron Age, 1928, Vol. 121, June 21, pp. 1739-1743). The assembly of motor-car rear axles by electric resistance welding at the plant of the Ford Motor Co. is described and illustrated.

The Assembly of Sections by Welding. H. Dustin. (Paper read before the Association Belge pour l'Étude et l'Essai des Matériaux, Jan. 18, 1928 : Revue Universelle des Mines, 1928, Vol. 19, Aug. 15, pp. 149-162). The manufacture of sections of various shapes by welding strip together, and the strength of the resulting products, are dealt with.

Welding Methods as Employed in Ironworks. E. Hinderer. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 87-97). A description of present-day practice in gas welding and electric welding. Data giving costs of welding by the two systems are included, conditions of operation are discussed, and examples of welds are shown.

The Present Status of Structural Steel Welding. F. T. Llewellyn. (Paper read before the American Iron and Steel Institute, Oct. 1928).

Arc Welding of Steel Structures. K. Bung. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 11, pp. 1105-1111). Comprehensive tests to prove the possibility of the production of steel structures by arc welding are described ; these show that the arrangement of the welds in relation to the stresses to which they will be subjected plays an important part in determining the maximum strength developed. Electrical welding provides a very satisfactory method of joining tubes. Examples of welds carried out in practice are given.

A Brief History of Arc Welding. A. Churchward. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 522-524).

Hints for the Electric Welding Operator. A. Churchward. (Heat Treating and Forging, 1928, Vol. 14, July, pp. 730-733, 763). Points to be observed in making good welds, and the causes of failure, are described in a practical manner.

The Working Conditions of a Resistance Welding Machine. M. Mathieu. (Arts et Métiers, 1928, Vol. 81, Oct., pp. 377–381).

Electric Cold-Welding of Heavy Cast-Iron Pieces. H. Kochendörffer. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 781–784). A number of examples of repairs of cast-iron machine parts in actual practice are described and illustrated ; in particular, the methods of preparing broken parts for welding are shown. According to the form adopted the welds are termed " anchor " welds, dove-tail welds, plate welds, or stud welds. The examples quoted were all welded with electrodes of soft Swedish charcoal iron wire, with a covering which produced an easily removable slag. It is important that the rate of solidification of the welding iron should be such as to allow time for the slaggy matter to rise to the surface. It is now more common to use nickel iron wire for the electrodes, as the tendency to take up nitrogen from the air is reduced thereby. The arc should be kept as short as possible in order to minimise the effect of the oxygen and nitrogen of the air.

Magnets Control Welding Arc. A. F. Davis. (Iron Age, 1928, Vol. 121, June 28, pp. 1810-1811). According to the author, welds of superior strength and appearance are produced by use of what is termed the " electronic tornado " carbon arc. A strong magnetic field is imposed on the arc flame, and this controls the arc and gives it a gyratory motion.

Fusion Welds on Heavy Plate. R. W. Miller. (Iron Age, 1928, Vol. 122, Sept. 6, pp. 567–570). The application of oxy-acetylene welding to the construction of pressure vessels is described, and comparative results are given of the tensile strengths of gas- and arc-welded joints.

Some General Thoughts on Fusion Welding. S. W. Miller. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 61–66). An explanation is given of the action of fluxes, and of the advantages of making rods for fusion welding of proper chemical composition, so that the resultant welds will be free from oxides. The advantages of higher strength and ductility obtained by the use of such rods are pointed out.

Atomic Hydrogen Welding in Production. P. C. Greene. (Iron Age, 1928, Vol. 122, Oct. 11, pp. 883–884). Several applications are noted of atomic hydrogen welding which utilises the electric arc in a stream of hydrogen gas.

A New Method of Making Joints. E. E. Thum. (Iron Age, 1928, Vol. 121, May 10, pp. 1305–1308). The method described is specially

adapted for making gas-tight joints in assembled steel parts. Copper in the form of wire, shot, or powder is placed in or near the joints of the part to be treated, and the part is then heated in an atmosphere of hydrogen in a specially designed furnace. During the process the copper penetrates into the joints and the surrounding metal, forming tight metal-to-metal connections completely welded.

Gas Welding of High-Chromium Corrosion-Resistant Alloys. W. B. Miller. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 43). Information is given on the welding properties of six groups of chromium alloys in wrought form, comprising stainless steel, three groups of stainless iron, high-chromium high-nickel alloys, and high-chromium alloys. The tensile and bend test properties of the three groups of stainless iron in the form of welded sheets are given, which show the value of welding the sheets after annealing. The importance of using a suitable flux in the welding of these alloys is emphasised.

Welding Chrome Irons and Steels. (Oxy-Acetylene Tips, 1928, Apr. ; Iron and Steel of Canada, 1928, Vol. 11, June, pp. 182–183). The irons and steels of this class are divided into groups according to their compositions, and the welding difficulties which they present are discussed. In general the operator must prepare clean joints, use a proper flux, and a strictly neutral flame, and complete the process with a correct heat treatment.

Welding of High-Chromium Alloys. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 502–504, 524). The procedure for welding various types of corrosion-resisting alloys is reviewed ; the importance of a proper flux to protect the work is stressed.

Welding of High-Chromium Alloys. (Acetylene Journal, 1928, Vol. 29, May, pp. 449–451). A survey is given of the correct procedure for the welding of various types of corrosion-resisting alloys.

Principles for the Examination and Acceptance of Plain (not Coated) Welding Rods. J. Fuchs. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 18, pp. 1151–1155). Welding rods and their characteristics are discussed. The effect of the chemical composition of the wire on the arc, the detection of non-metallic inclusions, hot-brittleness and losses by spurting, and the testing process are also dealt with.

Economies in Oxy-Acetylene Cutting for Riser Removal. G. O. Carter. (Paper read before the American Foundrymen's Association, May 1928). A brief discussion of the use of the oxy-acetylene cutting process for the removal of risers and gates from castings.

MISCELLANEOUS PRODUCTS.

Fabricates Starter Gear Blanks from Rolled Steel Bars. (Iron Trade Review, 1928, Vol. 83, July 5, pp. 8–10). The production of gear blanks at the plant of Dodge Brothers, Inc., Detroit, is described. Steel bars of the desired length are passed through a set of bending rolls, bent into an uncompleted circle, and then the two ends are welded. After trimming the blanks are normalised and quenched. They are then transferred to a hobbing machine which cuts the teeth on the periphery. After another heat treatment the gears are tested and then shrunk upon a flywheel.

Making Chain on Mass Production Basis. J. B. Nealey. (Iron Trade Review, 1928, Vol. 83, Aug. 30, pp. 503–505). The practice of the Chain Belt Co., Milwaukee, for the production of malleable iron and steel chain for conveyors is described.

Mass Production of Bolts and Nuts. G. A. Richardson. (Iron Age, 1928, Vol. 122, Oct. 25, pp. 1015–1021). **Manufactured Bolts by Modern Mass Production Methods.** G. A. Richardson. (Iron Trade Review, 1928, Vol. 83, Oct. 25, pp. 1051–1053, 1057). An illustrated account of the methods and equipment for large-scale production of nuts and bolts at the Lebanon plant of the Bethlehem Steel Co. A variety of methods and machines are in use for the manufacture of 3000 sizes and types of bolts and nuts. The heating furnaces serving the hot nut machines are fired with pulverised fuel.

Making Nuts and Bolts from Billets. F. W. Manker. (Iron Age, 1928, Vol. 122, Aug. 30, pp. 516–519). The operations involved in the production of nuts and bolts at the plant of the Buffalo Bolt Co., North Tonawanda, New York, are described. The rolling-mill includes two stands of 16-in. and six stands of 12-in. rolls in a continuous train, and five stands of 10-in. and two stands of 8-in. Belgian trains. Most of the furnaces in the hot forge department are of the box slot type, and many of them are gas-fired. The high-speed hot bolt heading machines are fed by wire in coils, the first end of one coil being welded on to the rear end of the preceding coil, so that the machines run without interruption. The wire passes first through the furnaces and then directly into the machine, which heads, shears, and ejects the bolts automatically.

Chinese Nail Mill Proves Profitable. K. F. Hwan. (Iron Age, 1928, Vol. 122, Sept. 13, p. 626). A short account is given of the equipment of the nail-making plant at the Kung Chin Ironworks, Shanghai.

Tru-Lay Wire Ropes and Tru-Loc Fittings. A. T. Adam. (Paper read before the North of England Institute of Mining and Mechanical Engineers, Oct. 20, 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Oct. 26, p. 622). The advantages of the Tru-Lay type of wire rope construction and the elastic properties of Tru-Lay ropes are discussed.

Materials of Aircraft Construction. A. Klemin and G. F. Titterton. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 518–521). The use of wires and stranded cables, and of rivets, and the application of various materials, are discussed.

PICKLING.

The Theory and Practice of Pickling. P. V. Blackburn. (Heat Treating and Forging, 1928, Vol. 14, May, pp. 498–499). A brief discussion of the principles that underlie the pickling operation. Directions are given for the proper procedure to secure the best results, and the action of inhibitors is described.

Pickling of Thin Sheets. F. Eisenkolb. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 693–698). The process of pickling thin steel sheets is considered under the following heads : The scaling of sheets, the use of hydrochloric and sulphuric acid, the reactions taking place in the pickling process, the addition of salts and inhibitors to the pickling agent, and the influence of the speed of acid attack.

Practical Features of Pickling. W. G. Imhoff. (Iron Trade Review, 1928, Vol. 82, May 10, pp. 1206–1209).

Pickling Influences the Spangle of Zinc-Coated Sheets. W. G. Imhoff. (Iron Trade Review, 1928, Vol. 83, Sept. 27, pp. 768–769, 780). The pickling of steel influences the development of the spangle to a large extent, and good quality steel properly pickled will develop a large fern-like spangle. The factors that cause small granular spangles originally develop in the steel-making process. Once developed, the only possible means still available to eliminate them entirely, or at least to minimise the effect of the development of hydrogen gas in the pickle, is to use a good inhibitor. Careful use of an inhibitor will also prevent burning, or over-pickling the surface.

On the Testing of Pickling Additions. H. Bablik. (Korrosion und Metallschutz, 1928, Vol. 4, Aug., pp. 179–181). The testing of the efficacy of pickling additions is briefly described, and the effects of these reagents on the pickling bath are discussed.

The Pickling of Metals with Regard to the Addition of Agents for Preventing Waste. W. H. Creutzfeldt. (Korrosion und Metallschutz, 1928, Vol. 4, May, pp. 102–107). The author discusses the use of various agents, mostly organic materials, which may be added to pickling baths to minimise the attack of the acid on the underlying metal, while not affecting the removal of the rust and dirt, and reports the results of tests with various of these agents.

COATING OF METALS.

(For Corrosion of Metals, see p. 435.)

Metal Protection in the Technique of Plating, with Particular Reference to the so-called Undercoating before Plating. E. Krause. (Korrosion und Metallschutz, 1928, Vol. 4, July, pp. 153–157). The properties and advantages of the various electroplated coatings are discussed.

Electrolytic Deposits of Metals. J. Roudnick. (Revue Universelle des Mines, 1928, Vol. 18, June 15, pp. 266–279 ; Vol. 19, July 1, pp. 21–31 ; Vol. 20, Oct. 15, pp. 53–65 ; Nov. 1, pp. 123–138). The author first discusses the theory and mechanism of electrodeposition and then describes, with much attention to details, the baths, conditions, &c., for nickel and chromium plating.

The Electrodeposition of Iron-Nickel Alloys. S. Gladstone and T. E. Symes. (Transactions of the Faraday Society, 1928, Vol. 24, July, pp. 370–378).

Polarisation and Resistivity in Nickel-Plating Solutions. R. L. Dorrance and W. C. Gardiner. (Paper read before the American Electrochemical Society, Sept. 1928). Using a Haring cell, the anodic and cathodic polarisations and resistivities of various nickel-plating solutions were measured at 17° C. The anodic polarisation was considerably reduced by the presence of chloride ions, although no appreciable difference was noted in the action of the metallic ions, potassium, sodium, ammonium, nickel, or magnesium associated with the chloride ions. The effect of bromide ions was the same as for the chloride ions, while the fluoride ions did not materially reduce anodic polarisation. Measurements were also made on other recommended solutions.

The Electroplating of Chromium. J. Cournot. (Mémoires de la Société des Ingénieurs Civils de France, 1928, Vol. 81, Mar.–Apr., pp. 303–311). The process and the advantages of chromium plating are briefly described, and the difficulties of the process are pointed out.

Influence of the Cathode on the Electrodeposition of Chromium.
H. S. Lukens. (Paper read before the American Electrochemical
Society, Apr. 1928; preprint No. 11). The production of passive
nickel by electrodeposition is reported. The influence of passive nickel,
of active nickel, copper, and lead on the composition of solutions for the
electrodeposition of chromium is studied and the results discussed.
Means for correcting the chromic salt and sulphuric acid content
of solutions for the deposition of chromium are indicated.

Steel Anodes for Chromium Plating. E. M. Baker and E. E.
Pettibone. (Paper read before the American Electrochemical Society,
Sept. 1928). Steel anodes are frequently used in chromium-plating
baths. The effects of variation in the percentage of carbon in the steel
on the rate of anode corrosion and on the oxidation of trivalent to
hexavalent chromium were studied. The steel having the lowest
carbon was most resistant to corrosion, and electrolytic iron was
more resistant than steel. The equilibrium concentration of trivalent
chromium was about the same for all of these anodes.

Porosity of Electrodeposited Chromium. E. M. Baker and A. M.
Rente. (Paper read before the American Electrochemical Society,
Sept. 1928). A study was made of the porosity of chromium deposited
from chromic acid chromium-plating baths. Within the thicknesses
of nil to 4×10^{-3} mm., a point of minimum porosity was found to exist
for all bath compositions and temperatures investigated. The thick-
ness of deposit necessary to give minimum porosity increases with
increasing bath temperature, but the least porous deposits can be
obtained at higher temperatures, about 55° C. The nature and
cause of porosity of electrodeposited chromium are discussed in some
detail.

Polish Essential for Chromium Plate. C. H. Eldridge. (Iron Age,
1928, Vol. 121, June 14, pp. 1680–1682). The author describes a
successful method for the polishing and preparation of metal surfaces
for chromium plating.

**The Application of Cadmium as a Protection against Rust by the
Udylite Process.** K. Gebauer. (Korrosion und Metallschutz, 1928,
Vol. 4, Sept., pp. 201–204). The author discusses the properties of
cadmium as a rust-protection for iron, and the most suitable baths
for its electrodeposition in a form which will give protection against
corrosion.

Automatic Cadmium Plating. (Iron Age, 1928, Vol. 122, Aug. 9,
pp. 341–342). The cadmium plating of brake shoes is done auto-
matically at the Fordson plant of the Ford Motor Co. Parts to be
treated are hung on suspension frames, which are placed on conveyor

hangers. A revolving arm picks the hangers off the conveyor and lifts them from tank to tank. The plating machine has a capacity of 3080 parts an hour, and three men are required to operate it.

Heating Problems in Hot Galvanising. W. G. Imhoff. (Heat Treating and Forging, 1928, Vol. 14, Oct., pp. 1197–1199). The author deals with the method of heating galvanising pots in relation to dross and to life of pots. Coke produces high dross, although the cause of high dross production can be generally attributed to faulty furnace design rather than to the kind of fuel. The relation between heating surface and dross production is shown.

Obtaining a Satisfactory Zinc Coating. W. G. Imhoff. (Iron Age, 1928, Vol. 122, Oct. 4, pp. 811–814). The author discusses some factors affecting the quality of zinc for hot galvanising. Lead does not seem to be harmful in zinc, as it alloys only in very small amounts and any excess settles to the bottom of the galvanising pot, and is entirely harmless unless it becomes too deep. Iron tends to make the zinc coating brittle and to decrease its resistance to corrosion. The presence of cadmium tends to produce very fine, small spangles, which in themselves are not attractive. Aluminium has been used in the zinc bath for some time and is very desirable when the bath is open— that is, not entirely covered with molten sal-ammoniac flux. It tends to give the coating a bright appearance, and keeps down excessive oxidation of the zinc. It is very desirable in obtaining a good spangle. Tin has also been used in the industry, and its presence has been found to produce large spangles on the sheets. Antimony tends to make the coating brittle, and will cause considerable trouble by giving a yellow discoloration on the sheet if present in too large a quantity.

A New Achievement in Galvanising. F. W. Young. (Industrial and Engineering Chemistry, 1928, Vol. 20, July, pp. 686–687). A method is described of electrolytically galvanising a large steel drum. The drum was mounted on bearings and rotated with only about one-fifth of its surface submerged in a galvanising tank. The speed of rotation had to be slow enough to allow the coating to deposit, and fast enough to prevent oxidation and drying of the surface exposed to the air. The method is briefly described.

Report of Sectional Committee on Specifications for Zinc Coating of Iron and Steel. (American Society for Testing Materials, June 1928, Preprint No. 26). Specifications for zinc (hot-galvanised) coatings on structural steel shapes, plates, and bars, and their products ; and also specifications for zinc coating on iron and steel sheets are given.

A Few Notes on the Hot Tinning of Wrought Iron Articles. E. Bertrand. (Arts et Métiers, 1928, Vol. 81, Sept., pp. 343–347). The

process of tinplating is discussed. The influence of the quality of the sheets on the product is indicated.

Practical Recovery of Tin from Tinplate. V. Weinod. (Metal Industry, 1928, Vol. 33, Oct. 19, p. 376). Brief particulars are given of a new electrolytic process for the recovery of tin from tinplate scrap.

An Electric Enamelling Furnace. H. Kalpers. (Die Giesserei, 1928, Vol. 15, Oct. 19, pp. 1060–1062). The Brown-Boveri electric furnace described in this article gives very even heating, and the temperature is easily controlled.

Enamelling, with Particular Reference to Modern Enamelling Ovens. A. Bresser. (Korrosion und Metallschutz, 1928, Vol. 4, July, pp. 157–160).

Conveyors Shorten Enamelling Time. F. M. Reiter. (Iron Trade Review, 1928, Vol. 82, May 24, pp. 1337–1341). **Enamel and Lacquer Coatings Baked in Vestibule-Type Ovens.** F. M. Reiter. (Iron Trade Review, 1928, Vol. 82, May 31, pp. 1401–1403). These two articles describe and illustrate the practice of the National Cash Register Co., Dayton, Ohio, for the lacquering and enamelling of steel cabinets.

The Wet Process of Vitreous Enamelling. W. Marshall. (Foundry Trade Journal, 1928, Vol. 39, Nov. 15, pp. 363–364).

A Test for the Adhesiveness of Vitreous Enamels to Metal. W. N. Harrison and G. T. Thaler. (Journal of the American Ceramic Society, 1928, Vol. 11, Nov., pp. 803–811). A method of testing the adhesiveness of vitreous enamels to metals has been developed. Specimens are prepared by clamping together two strips of enamelled metal while in the furnace and allowing them to cool slowly from a temperature of 500° C. The test consists of determining the force necessary to pull the two metals apart when treated as a continuous strip of metal under tensile stress. An estimate is made of the percentage of contact area on each specimen within which failure occurred in the bond. The adhesiveness of an enamel containing cobalt, manganese, and nickel oxides is compared with an enamel free from these oxides. The cobalt enamel gave a much stronger bond, a result which is in agreement with industrial experience.

Progress Report on Cast Iron for Enamelling Purposes. W. N. Harrison, C. M. Saeger, jun., and A. I. Krynitsky. (Journal of the American Ceramic Society, 1928, Vol. 11, Aug., pp. 595–608). Blisters on enamelled cast-iron ware may be traced either to faulty enamels and process of application or to the castings themselves. Differences in the blistering tendencies of different sets of casts were clearly brought

out by an enamelling test, which included a variety of firing treatments. It was found that not only do different irons have different blistering tendencies, but successive heats of the same iron may also vary. The main cause of blisters was overcome by removing a thin surface layer of the castings either by mechanical or chemical means.

Chipping and Abrasion Tests for Paint Coatings on Metal. A. D. Camp. (Industrial and Engineering Chemistry, 1928, Vol. 20, Aug., pp. 851–852).

The Protection of Iron Against Corrosion by Painting. E. Schumacher. (Stahl und Eisen, 1928, Vol. 48, Sept. 13, pp. 1288–1293). A general report on the manner in which corrosion in steel structures may be checked by the avoidance of certain structural defects ; with notes on the painting of steel structures and testing the rust-preventive qualities of paints.

Accelerated Tests of Organic Protective Coatings. P. H. Walker and E. F. Hickson. (Bureau of Standards Journal of Research, 1928, Vol. 1, July, pp. 1-17). Methods and equipment used at the Bureau of Standards for accelerated tests of paints, varnishes, lacquers, bitumens, &c.

On the Treatment of Ferrous Alloy Parts in Solutions of Complex Phosphates, with a View to Protection against Corrosion. J. Cournot. (Comptes Rendus, 1927, Vol. 185, Nov. 14, pp. 1041–1043). The method consists of treating the iron or steel in boiling acidified baths containing 3 to 4 per cent. of iron and manganese phosphates prepared from orthophosphoric acid. The iron phosphate formed soon reaches the supersaturation point and a deposit of complex phosphates forms on the metal. The fine black coating formed is very resistant to atmospheric corrosion and provides a very good anchorage for supplementary protective coatings. The properties of the metal are not modified. Comparative tests under various conditions of the coating and of other usual protective films show that the former is at least as good and frequently much better a protection in the atmosphere than the other agents.

PHYSICAL AND CHEMICAL PROPERTIES.

PROPERTIES AND TESTS OF CAST IRON.

Effect of Various Elements on Malleable Cast Iron. L. E. Gilmore. (Paper read before the American Foundrymen's Association, May 1928). A discussion of the more important effects of various elements and compounds on malleable cast iron. The subject is dealt with under the following headings : Essential condition of carbon ; effect of phosphorus ; manganese-sulphur ratio ; silicon-carbon balance ; low carbon with high silicon ; aids to graphitisation ; and inhibitors of graphitisation.

Whiteheart Malleable Tests. E. R. Taylor. (Bulletin of the British Cast Iron Research Association, 1928, No. 22, Oct., pp. 55–58). The testing of malleable castings is discussed, with special reference to the size of test-bars for thin-walled castings.

Effect of Sulphur on Physical Properties of Grey Iron. E. K. Smith and F. B. Riggan. (Paper read before the American Society for Testing Materials, June 1928). The authors present the results of tests carried out to determine the effect of sulphur on microstructure, machinability, Brinell hardness, transverse strength, tensile strength, contraction, and fluidity.

Report of Committee A3 on Cast Iron. (American Society for Testing Materials, 1928, Preprint No. 11). The results of tension and transverse tests of Standard A.S.T.M. arbitration bars of varying dimensions are submitted.

The Static and Fatigue Properties of Some Cast Irons. J. B. Kommers. (Paper read before the American Society for Testing Materials, 1928, Preprint No. 40). The paper reports the results obtained in the testing of ten series of cast irons, each series comprising 31 bars cast in the form of the A.S.T.M. Standard arbitration bar. A complete history of the iron in each series is given, with chemical analyses and metallographic properties.

The tests include tension tests on two different sizes of specimens, compression tests, impact tests, transverse tests, Rockwell and Brinell hardness tests, and fatigue tests. The properties of two high-duty

cast irons in the series are discussed, and the effects of nickel and chromium additions are pointed out.

The several properties of the irons are compared; and it is shown that while the fatigue endurance limit of cast irons may be roughly estimated from properties, such as tensile strength, hardness, and modulus of rupture, knowledge of the effect of available factors in influencing the properties of cast iron is so meagre that such approximate estimates of endurance limit should always be checked by direct experiment. No consistent relation was found between endurance limit and chemical composition.

The paper suggests the need of further study along several lines, such as influence of melting and pouring temperatures, heat treatment of castings, and effect of alloy additions.

Engineering Tests of Cast Iron. J. G. Pearce. (Journal of the West of Scotland Iron and Steel Institute, Session 1927–1928, Vol. 35, pp. 80–90).

The Use and Interpretation of the Transverse Test for Cast Iron. J. G. Pearce. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 73).

Round *versus* **Square Transverse Bars for Grey Cast Iron.** J. G. Pearce. (Engineer, 1928, Vol. 146, Oct. 19, p. 437). The author commences by advocating the use of the rupture modulus rather than the breaking load to express the transverse strength of a test-bar ; the principal difficulty encountered in the change is arithmetical, and he presents a graph giving the rupture modulus under standard testing conditions for any breaking load over a range of diameters above and below 1·2-in. and 2·2-in. nominal sizes, covering any ordinary casting tolerance. The author then discusses the results obtained on round and square test-bars and reports the following figures for tests, carried out by Norbury in the British Cast Iron Research Association's laboratories :

Rupture Modulus.

Bars cast round, tested round :				average	28·7	tons per sq. in.	
,, ,,	square,	,,	round :	,,	28·6	,,	,,
,, ,,	round,	,,	square :	,,	25·5	,,	,,
,, ,,	square,	,,	square :	,,	25·4	,,	,,

The author states that clearly the difference between the two shapes cannot be due to casting conditions, and must therefore be due to testing conditions. In particular, the differences between the moduli of the actual and nominal sections for the two shapes cannot be the same.

The Metallurgical Aspects of Cast Iron. P. W. Blackwood. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 1021–1038). The complex character of cast iron is pointed

out, and various factors which influence the properties are discussed. The work of various investigators on the effect of various elements in cast iron is dealt with at length, also some recent methods for the production of pearlitic cast iron.

Mechanical and Physical Properties of High-Duty Grey Cast Iron and Principles Underlying its Production. E. Zimmermann. (Zeitschrift für die gesamte Giessereipraxis, 1928, Vol. 49, Mar. 11, pp. 104–105; Mar. 18, pp. 111–112; Apr. 20, pp. 159–160; May 6, pp. 166–167; May 13, pp. 175–176).

Examples of Some Peculiar Graphite Crystallisations in Pig Iron and Cast Iron. H. Pinsl. (Stahl und Eisen, 1928, Vol. 48, Apr. 12, pp. 473–477). In the stable iron-carbon system the separation of the ferrite-graphite eutectoid marks the end of the course of transformation. Hitherto, so far as the author knows, it has not been possible to detect by metallographic means this eutectoid in castings or pig iron with an entirely ferrite ground-mass. The eutectoid corresponds with pearlite in the iron-carbide system. The separated graphite of the eutectoid crystallises into the existing graphite veins, and is thus withdrawn from observation as a separate constituent. There are, however, cases where the formation of an iron-graphite eutectoid may be recognised in a prepared section. Some examples of such are shown. The formation of the primary graphite and the graphite of precipitation in the presence of iron phosphides can be brought about by very long annealing and very slow cooling. Observations are also made of the occurrence of graphite nuclei in the section according to the theory of Hanemann, and attention is directed to the characteristic structure of graphite deposits and temper carbon spots.

Theory or Practice in Grey Iron Foundry. J. Shaw. (Paper read before the American Foundrymen's Association, May 1928). The author puts forward a number of problems to be considered in the investigation of cast iron. The relationship of the various elements to the resulting iron properties, melting temperatures, and size of test-bar are discussed. In the study of cast iron the author questions whether it is better to use a cast-iron base and make suitable variations on that rather than use a pure iron-carbon base, as in the study of carbon steel.

The Theory of Cast Iron. A. B. Everest. (Foundry Trade Journal, 1928, Vol. 39, Sept. 27, pp. 223–227). In the solidification and cooling of iron-carbon alloys four successive forms of carbide are developed, and there is evidence to show that these forms have their counterpart in the forms of graphite developed under the conditions which cause the alloy to solidify and cool according to the iron-graphite system. The forms of carbide and graphite are explained and illustrated. The

influence of composition and thermal history on the ultimate structure of cast iron is discussed, and it is shown how the different structures can be explained according to the theory propounded by D. Hanson (Journ. I. and S.I., 1927, No. II. p. 129).

Comment on D. Hanson's Work, '' The Constitution of Silicon-Carbon-Iron Alloys, and a New Theory of the Cast Irons.'' E. Scheil. (Die Giesserei, 1928, Vol. 15, Oct. 26, pp. 1086–1088). The opinion expressed in Hanson's paper (Journ. I. and S.I., 1927, No. II. pp. 129–169) that in the binary and ternary systems equilibrium may be attained between graphite and cementite, and that the double diagram is at variance with the Phase Rule, is criticised.

Constitution of Cast Iron. (Iron and Steel Industry, 1928, Vol. 1, Sept., pp. 368–370, 386). The iron-carbon equilibrium diagram is touched upon, and the functions of the elements contained in the iron are explained. The mixing of cast iron and the influence of the constituents on its properties are also discussed.

Grey Cast Iron. J. E. Hurst. (Lecture to the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Oct. 18, pp. 281–282). A review of various attempts made to devise a formula to express the relation between the composition and properties of cast iron. The cast-iron diagrams of Maurer, Greiner and Klingenstein, and Thrasher are discussed.

The Critical Points and the Martensitic Quenching of Nickel and Nickel-Chrome Cast Irons. L. Guillet, Gallibourg and Ballay. (Paper read before the Académie des Sciences, July 2, 1928 : Génie Civil, 1928, Vol. 93, July 14, p. 41). A brief note on the martensitic quenching of cast irons containing nickel and nickel-chrome, with results of experimental determinations of the hardness of various irons after various quenching treatments. The effect of the various elements in the metal on the quenching phenomena are recorded.

On the Mechanical Properties of High-Duty Cast Iron, with Special Reference to its Machinability. W. Melle. (Giesserei-Zeitung, 1928, Vol. 25, Oct. 1, pp. 557–567 ; Oct. 15, pp. 596–602). The author discusses the structure of high-duty cast iron and describes briefly the various processes by which it is produced. He then describes his own experiments to determine the relationship between the tensile, compressive, and bending strengths, and to discover the dependence of the machinability on the Brinell hardness. For the machinability tests he used Kessner's apparatus by which the depth of hole bored by a standard drill under a known load in 100 revolutions is recorded graphically.

The Speed of Solution of Graphite in Molten Iron-Carbon Alloys.
F. Sauerwald and A. Koreny. (Stahl und Eisen, 1928, Vol. 48, Apr. 26, pp. 537–540). The apparatus used and the test results obtained in the investigation of the speed of solution of graphite in molten iron-carbon alloys at 1255° and 1350° C. are described ; the results were in substantial agreement with those of Noyes, Withney, and Nernst. The speed of solution was found to be proportional to the surface of the graphite and to the degree of saturation of the melt ; its magnitude was such that the complete solution of graphite particles such as occur in commercial cast irons would require a considerable time, particularly at lower temperatures, comparable to the period allowable for melting the iron. The influence of the temperature on the speed of solution was very marked.

Internal Chill in Cast Iron. J. E. Hurst. (Iron and Steel Industry, 1928, Vol. 1, July, pp. 301–303). The author discusses the various explanations of the cause of internal chill put forward by various investigators, and points out in what respects they fail. His own opinion is that the phenomenon is connected with the rate of cooling ; there is a critical rate of cooling for the precipitation of graphite, and he pictures the case of the rate of cooling of a spot near the surface, when the graphite precipitation temperature is passed, being actually less than the rate of cooling at the corresponding moment of a spot some distance inside the metal.

The Influence of Carbon, Manganese, and Silicon on the Growth of Cast Iron. O. Bauer and K. Sipp. (Die Giesserei, 1928, Vol. 15, Oct. 12, pp. 1018–1026 ; Oct. 19, pp. 1047–1060). The authors define the distinction between primary and secondary growth. The former is due to the decomposition of carbide into ferrite and graphite and does not attain to large amounts. It does, however, cause the formation of minute cavities in the metal, and secondary growth, which may attain to serious proportions, takes place in these cavities by oxidation and corrosion. Primary growth is influenced by the chemical composition ; silicon promotes it, and manganese hinders it. In high-silicon, low-manganese irons, carbon appears to assist the action of the silicon ; in high-manganese irons, however, even with high silicon, it appears to be without effect. Ferrite and graphite when already present act as nuclei and hasten the process of growth. The density of the metal also has an effect.

The Applicability of Cast Steel in Comparison with Grey and Malleable Cast Iron. F. Herkenrath. (Die Giesserei, 1928, Vol. 15, Oct. 5, pp. 993–996). The author's opinion is that in only very few cases can cast steel supplant cast iron ; on the other hand, malleable cast iron is competing more and more with cast steel.

On Acid-Proof Cast Iron. F. Espenhahn. (Die Giesserei, 1928, Vol. 15, Sept. 14, pp. 917–921). The author discusses the Fe–Si and Fe–Si–C diagrams and the compositions of the technical alloys, and comments on the physical and chemical properties of silicon iron. The manufacture of silicon alloys—design, moulding, the mixture, melting, casting, shaking out, and cleaning—is described.

The Behaviour of Cast Iron under Dynamic and Static Compression. B. Garre. (Die Giesserei, 1928, Vol. 15, Aug. 10, pp. 792–793). Statically compressed cast iron has less ability to change its shape up to the appearance of the first cracks than has dynamically compressed iron. With increasing pearlite contents the ability to change shape increases more rapidly under dynamic than under static compression.

On the Hardness Testing of Cast Iron. H. Pinsl. (Giesserei-Zeitung, 1928, Vol. 25, July 15, pp. 417–424 ; Foundry Trade Journal, 1928, Vol. 39, Sept. 27, p. 228). A general discussion on the processes for testing the hardness of cast iron is followed by details of experiments on phosphorus-rich irons to determine the relationships between Brinell, Poldi, and scleroscope hardnesses. Hardness and structure are discussed.

The Displacement of Cast Iron by Rolled Steel. Amelsitz. (Giesserei-Zeitung, 1928, Vol. 25, Apr. 1, pp. 226–227). The reasons for the choice of rolled steel for various structural parts formerly made of cast iron are discussed, and suggestions for winning back the position once held by cast iron are put forward.

On Nickel and Chrome Alloy Cast Iron. E. Piwowarsky. (Die Giesserei, 1928, Vol. 15, Oct. 26, pp. 1073–1078). The experimental results contained in the literature of the subject concerning the influence of nickel or chromium or a combination of the two on cast iron are discussed.

Contributions to the Knowledge of Graphite in Grey Cast Iron and its Influence on the Strength. P. Bardenheuer and K. L. Zeyen. (Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, 1928, Vol. 10, pp. 23–53). A rapid survey of the development of the investigation of cast iron indicates the basic principles upon which the improvement of the material must rest. Various theories on the formation of graphite supply a satisfactory explanation of the phenomenon on which to base attempts to influence it usefully. Experiments are described which demonstrate that with increasing superheating temperatures the graphite nuclei tend more and more to disappear from the structure, cupola irons needing higher temperatures to destroy the nuclei than clean pig irons. Experiments with slowly cooled specimens revealed that with increasing degrees of superheat there is

an increasing replacement of the coarse graphite plates by the fine graphite eutectic and a growing tendency towards the solidification of carbide ; they supplied a simple explanation of the renewed increase of the graphite relative to the total carbon found at high superheat temperatures.

An account of published work dealing with the influence of the amount and form of graphite on the strength of cast iron is followed by details of the authors' very numerous tests. Sand-cast samples with normal silicon showed maximum strength with from $2 \cdot 5$ to $2 \cdot 7$ per cent. of carbon, but in a series with $3 \cdot 5$ per cent. of silicon this maximum value was not attained. Chill-casting followed by anneal-ing produced a considerable increase of strength over sand-casting ; this was primarily due to the form of the graphite, the ground-mass having only a small effect. If, however, the interruption of the metallic continuity by coarse graphite plates was first prevented, then influences acting on the ground-mass could increase the strength still further. Maximum strength was observed in specimens containing temper carbon, and not in those with eutectic graphite. The effect of varying superheat on the structure and strength of chill castings was also investigated. Other tests showed that the casting temperature had an effect only on material which had not been superheated : the reason why in non-superheated cupola irons there is a tendency for the graphite to be coarser at lower than at higher casting temperatures is given. Attempts to improve normal cupola irons by jolting were entirely negative. Sixteen tables and 176 illustrations accompany the paper.

Bardenheuer and Zeyen's Paper Criticised. J. Shaw. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Nov. 22, pp. 377–378 ; Nov. 29, pp. 395–399). A critical discussion of the investigations of Bardenheuer and Zeyen on the influence of graphite on the mechanical properties of grey cast iron.

Alloy Cast Iron. D. Hanson. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Nov. 1, pp. 319–321 ; Nov. 8, pp. 337–340). The influence of nickel and nickel and chromium on the properties of cast iron is discussed. Additions of nickel with or without chromium can be effective in controlling chill, increasing and equalising hardness, raising the strength and improving the machinability. These effects are due to the characteristic action of nickel in decomposing eutectic and pro-eutectoid carbide, while maintaining a high combined carbon in the matrix on which its refining and sorbitising action can take effect. It is, however, necessary in making nickel additions to take into account not only the fundamental action of this element, but also the influence of the other elements that may be present in the iron. The characteristic action of nickel is effective in the presence of both chromium and phosphorus, and can

be utilised with advantage in the presence of those elements, provided that due attention is also given to the characteristic effects of those elements themselves.

The Heat Treatment and Volume Changes of Grey Cast Irons between 15° and 600° C. J. W. Donaldson. (Paper read before the Association Technique de Fonderie: Foundry Trade Journal, 1928, Vol. 39, Oct. 25, pp. 299–303; Nov. 1, pp. 315–318). The investigation described is in two parts, the first dealing with the influence of heat treatment on decomposition of combined carbon, strength, and hardness, and the second with volume changes between 15° and 600° C. The composition of the various irons used in the investigation, together with their tensile strengths and Brinell hardnesses as cast, are tabulated and arranged in series according to the variation of one constituent. The methods of testing are outlined, and the results obtained are discussed. The changes in strength and hardness of grey cast iron are due to the decomposition of the combined carbon, and are influenced by the temperature of treatment, the duration of treatment, and the composition. As the total carbon content is increased from 2·71 to 3·51 per cent., the stability of the combined carbon and consequently the heat-resisting properties are decreased. Increase of manganese from 0·52 to 2·43 per cent. produces a uniform increase in the heat-resisting properties. The influence of increasing the phosphorus from 0·20 to 1·06 per cent. is to produce a slight but uniform increase, and that of silicon has a marked effect on the heat-resisting properties. The extent of growth is dependent in the first place on the dimensions and form of the graphite after decomposition of the combined carbon; and, secondly, on the relative amount of oxidation, factors which are controlled by the composition of the iron.

Temperature Measurements of Molten Cast Iron. H. T. Wensel and W. F. Roser. (Paper read before the American Foundrymen's Association, May 1928). Measurements of the true temperature with a thermocouple and apparent temperature with an optical pyrometer on molten cast iron show that the character of the surface undergoes a change in the neighbourhood of 1375° C. true temperature. Observations on streams and ladles in the Bureau of Standards foundry and in commercial plants all indicate that the uncorrected optical pyrometer reading is approximately 40° C. lower than the true temperature below 1375° C., when the bright presumably oxidised surface is observed. This corresponds to an emissivity of 0·7 in this region. Above this region the emissivity is approximately 0·4, corresponding to a correction of 110° at 1400° C. and 140° at 1600° C. true temperature.

The change in emissivity is attributed to the formation of iron oxide below 1375° C. Above this temperature the difference between true and apparent temperature corresponds to the emissivity found for pure iron in the laboratory.

PROPERTIES AND TESTS OF IRON AND STEEL.

The Requirements in Testing Apparatus for Practical Use. M. Moser. (Stahl und Eisen, 1928, Vol. 48, Sept. 27, pp. 1362–1370). A number of testing machines are described and illustrated, and the essential features which they should possess are discussed. The types include tensile, bending and hardness testing machines, and machines for long-time tests by stress reversal.

The Mechanical Testing of Metals. (Metal Industry, 1928, Vol. 32, Apr. 6, pp. 345–348 ; Apr. 27, pp. 417–420 ; June 1, pp. 537–541 ; Vol. 33, Sept. 7, pp. 221–225). A series of elementary articles discussing the underlying principles of the tests made on metals. The mathematics involved have been reduced to a minimum.

Reception Tests for Structural Steels. C. Frémont. (Génie Civil, 1928, Vol. 93, Aug. 11, pp. 133–135). The author describes the taking of very small test-pieces from structural steel, such as could be taken from scraps of metal, the punchings from rivet holes, &c. ; his specimens are about 3 mm. thick, 4 mm. wide, and 16 mm. long. He also describes some small machines for testing these tiny specimens, and he outlines generally the system of making these diminutive tests, with comments on the results obtained and their meaning.

Universal Machine for Testing the Hardness, Static Flexion, and Shear Strength of Castings, and Machine for Applying the Cupping and Tensile Tests to Sheet Metals. R. Guillery. (Bulletin de la Société d'Encouragement, 1928, Vol. 127, June, pp. 483–502). Various machines manufactured by the author for testing the mechanical properties of metals are illustrated and described.

Procedure for Simplified Testing. G. D. Johnson. (Heat Treating and Forging, 1928, Vol. 14, Aug., pp. 870–874). The author describes various simple means of testing steel in the works, such as the spark test to distinguish the different grades and types of steel, the shear test for defects—fibre, laminations, or pipe—deep etching for non-metallic inclusions, porosity, hair-lines, internal cracks, and hard spots, and the file test on a quenched specimen to determine any decarburisation, &c.

Machines for Testing the Strength of Metallic Materials. W. Deutsch and G. Fiek. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 25, pp. 1173–1182).

Machines for Hardness Testing, Technological Research, and Acceptance Tests on Metallic Materials. W. Deutsch and G. Fiek. (Zeit-

schrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Oct. 27, pp. 1541–1546).

Strain Markings in Mild Steel Under Tension. H. S. Rawdon. (Bureau of Standards Journal of Research, 1928, Vol. 1, Sept., pp. 467–485). Polished bars were examined during a tensile test to determine the stress and corresponding elongation at which strain markings appear. The first appearance of the strain markings on the surface of the bar coincided with the yielding of the metal, and indicated the proportional limit of the metal very closely. Hardness increases about 5 per cent. during the formation of strain markings, this increase being about one-tenth of that occurring when the same steel is stressed to fracture. Strain markings result from deformation by slip within a relatively few suitably oriented ferrite grains. This slip is accompanied by a general shifting and tilting of neighbouring grains, however, which results in the characteristic rippled surface appearance of strain markings on steel. Similar markings were observed on an aluminium alloy.

Study of the Tensile Test on Metals. C. Frémont. (Études Expérimentales de Technologie Industrielle, Mémoire ⁊72, 1927). The author commences by describing the origin of the tensile test, and he reviews the history of its development. He next points out the objections to the tensile test which have been raised by various experts, and discusses the principal factors which may cause the results to be faulty, giving examples of cases where material which had responded well to the test had failed in practice. Then follows a discussion of the various properties of metals called into play in the test, and the phenomena which accompany it. He discusses Wöhler's theory and the behaviour of metals subjected to repeated stresses.

Modulus of Elasticity. L. Persoz. (Aciers Spéciaux, 1928, Vol. 3, Oct., pp. 189–191). The author discusses the work of other investigators on the elastic modulus of steels with nickel, chromium, and manganese as alloying elements.

The Yield Point of Steel. W. Kuntze and G. Sachs. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, July 21, pp. 1011–1016). In a number of tests on steel, particularly silicon steel, the changes of cross-section along the whole length of specimen were measured as the yield point was passed. The first marked deformation usually occurred as a constriction on releasing the load which, in uniform pieces at approximately constant load, broadened out until the whole piece had become cylindrical again. Further deformation produced a uniform extension over the whole specimen. The first constriction was due to failure of a brittle spot, for it always occurred in the head or at a slightly damaged place, while the final constriction always occurred at the middle or at the weakest spot. The process

could not be regarded as a simple mechanical phenomenon in a body built up of iron and cementite, for on ageing at a low temperature a piece previously stretched a fresh constriction on releasing the load could be obtained.

The Use of the Yield Point for Calculations and for Acceptance. Kühnel, Mohrmann, and Karth. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Sept. 1, pp. 1226–1232). The exceptions to the reliability of the yield point are discussed, such as the scattering of the values with round and flat test-pieces of carbon steel, copper steel, and silicon steel; the influence of the speed of pulling, shape of head, cross-section, notch-action, &c., in the case of certain specified steels is discussed. The influence of the shape of the cross-section is dealt with, and proposals for changing the standards are put forward.

Shock Tensile Testing of Steel. P. Regnauld. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, May, pp. 262–271). The author first discusses shock tensile testing methods, and describes briefly the "reverser" which he used; with this device a blow delivered by a falling tup is transmitted to the lower end of a vertical test-piece, the top of which is rigidly supported, thus producing a shock tensile stress. By this means the author made tests on specimens of various contours. He also tried the Charpy pendulum tup on plain test-pieces (in tension) and repeated Maitland's explosion test. He then applied the Charpy machine to the testing of notched tensile test-pieces. He concludes that the plain test-pieces gave no evidence regarding brittleness. The results with notched specimens were satisfactory and could be duplicated. He thinks it possible to determine a "resilience" analogous to ordinary resilience. With regard to brittleness shock tensile tests should be superior to transverse impact tests, because the stresses are simpler and fracture occurs at a well-defined plane. The proneness to intercrystalline cracking can be evaluated in a more realistic manner; if a fibrous steel be tested in the ordinary way a little fibre will always be found in the fracture, but in such a steel shock tension tests always produce a crystalline fracture. In the case of a burst piece of gun tube the shock tensile test was the only one that revealed the presence of brittleness. Despite its crudeness the author considers the test more precise than any other.

The Registration of the Elastic Work of Materials. The MacCullum-Peters Electric Elastograph. P. Caufourier. (Génie Civil, 1928, Vol. 93, Aug. 18, pp. 165–168). After a brief review of various appliances for measuring the elastic working of structural parts under the influence of loads, the author describes the MacCullum-Peters device. The expansion or contraction of the part under test is caused to apply similar forces to the ends of a pile of annular hard-carbon discs which form one of the resistances in a Wheatstone bridge; the

alteration of the resistance so produced is measured by rebalancing the bridge in the usual way. In the simple machine the curve relating the variation of resistance to the change of length is an equilateral hyperbola. In the " double base " instrument, the action of the test-piece is applied at the middle of the pile of carbon discs, so that as one half is compressed the other half is relaxed ; each half forms one resistance in the Wheatstone bridge, and in this case the relation of the total change of resistance to alteration of length is practically linear.

The Fracture of Notched Tensile Test-Bars. W. Kuntze. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 109–117 ; Stahl und Eisen, 1928, Vol. 48, Sept. 6, p. 1247). It is well known that ductile materials under certain conditions will manifest brittleness and show a brittle fracture. The form and depth of the notch in notched test-pieces has a great influence on the degree of deformation of the piece before fracture. These considerations have led the author to define the cohesive strength of a material as that stress which will produce fracture in a bar in which all elongation or any kind of deformation is prevented. As this is impossible in practice, the value of the stress has to be calculated by making fracture tests on bars with increasing depths and diminishing angles of notch and determining the required value by extrapolation.

Long-Time Testing, Structure, and Damping. W. Herold. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 23–39). The results are reported of a series of long-time tests on annealed and heat-treated pearlitic and hardened martensitic steels. The tests were made on a Schenck long-time bend-test machine, and the changes in the micro-structure and damping were observed. For each material the lower " long-time test strength " was determined—that is, the maximum load which the specimen will permanently endure, when exposed suddenly to its full effect, and this value is proposed to be adopted as characterising the particular material. By slowly increasing the load, the value of the " long-time test strength " can be raised, an increase of 30 per cent. being noted in one case. Long-time testing produces quite a marked change in the structure. In the case of annealed and quenched pearlitic and martensitic steels this alteration consists in a separation of the two solid phases. The harder phase is driven to the grain boundaries, which show up more clearly, and the structure in consequence appears to be coarsened. In the case of pearlitic steels the cementite migrates to the grain boundaries. The structure after fracture consists in the neighbourhood of the fracture of ferrite with granular pearlite at the grain boundaries. The " damping " of the materials was also investigated, damping being the capacity for energy to be transformed into heat due to internal friction. As the number of alternations of the load increase, damping diminishes and may

disappear altogether even in those materials which had a high damping capacity at the start. A change of structure takes place at the same time, and it is possible from the type of structure of a material to judge its capacity for damping.

"Long-Time" or "Flow" Tests of Carbon Steels at Various Temperatures, with Particular Reference to Stresses below the Proportional Limit. J. J. Kanter and L. W. Spring. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 35). The authors discuss the attempts that have been made to arrive at a satisfactory short-time method for estimating the rate of flow of steel at different stresses. A description is given of twelve flow-testing machines with temperature controls and measuring apparatus. Flow curves of various carbon steels are given and discussed, as is also the effect of grain-size. Steels which have undergone small amounts of flow do not seem to have deteriorated, the tensile properties, including elongation and reduction of area, remaining approximately what they were before the flow tests. Since little or no deterioration occurs or should be expected (unless through oxidation), and since with ductile metals at temperatures above 600° F., 10 per cent. or more of flow or elongation are necessary before the material starts out on its final stretching preceding rupture, it is argued that any slight flow or deformation brought about by stresses below the proportional limit should be regarded as distortion only and not seriously objectionable unless such distortion interferes with service. Usually the factors of safety employed are sufficient, but if stresses are reached which produce flow there is little probability of rupture with danger to life and property until at least 10 or 15 per cent. of total flow or distortion has taken place.

Rapid Determination of Resistance to Long-Time Alternating Stress. O. v. Bohuszewicz and W. Späth. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 249–254). An illustrated description is given of an apparatus for rapidly determining the capacity of a material to withstand alternating stresses applied for a long time. The specimens are subjected to vibratory torsional stresses applied by a motor with 2 coils, one supplied with direct current, the other with alternating current at 50 cycles. The armature provided with short circuit winding makes vibratory turns according to the frequency of the exciting a.c.

Fatigue Resistance of Rail Steel. J. R. Freeman, jun. (Iron Age, 1928, Vol. 121, June 21, pp. 1743–1745).

Researches on Springs. I.—The Endurance of Spring Steel Plates under Repetition of Reversed Bending Stress. G. A. Hankins. (Department of Scientific and Industrial Research, Engineering Research, Special Report No. 5, 1928).

Torsional Fatigue Tests on Spring Steels. H. A. Hankins. (Department of Scientific and Industrial Research : Engineering Research, Special Report No. 9, 1928). The resistance to torsional fatigue is of primary importance in the application of spring steels to the manufacture of helical springs, and the tests described have been devised with a view to disclosing the actual properties of the materials under torsional stress cycles. A description is given of the testing machine constructed for the investigation. The results of tests on numerous specimens show in general that the values of the safe ranges for reversed and repeated stresses are roughly proportional to the tensile strengths of the various materials ; the ratios of the safe ranges for reversed stresses to the ultimate tensile strengths are about the same as those obtained for normalised steels in the Stromeyer machine. For hardened and tempered spring steels the chrome-vanadium steel was slightly superior to the $0 \cdot 6$ per cent. carbon steel tested, although the tensile strengths were the same. Silico-manganese steel, although of greater tensile strength than the chrome-vanadium steel, did not give higher safe ranges. The experimental values definitely confirm McAdam's conclusion that variations of the safe ranges within the elastic ranges are small. In addition, the present results show that the variations are small when the superior stress limits are well outside the original elastic or proportional ranges. In the case of mild steel and normalised $0 \cdot 6$ per cent. carbon steel, the safe ranges were less than 10 per cent. below those for reversed stresses even when the superior limits of stress approached the ultimate stresses of the materials. In the case of hardened and tempered spring steels there were marked decreases in the safe ranges at the high mean stresses, but the results were still considerably above the modified Goodman values.

What is Fatigue ? K. Laute and G. Sachs. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Aug. 25, pp. 1188–1189). The work of other investigators is briefly reviewed.

Fatigue Phenomena, with Special Reference to Single Crystals. H. J. Gough. (Journal of the Royal Society of Arts, 1928, Vol. 76, Sept. 7, pp. 1025–1044 ; Sept. 14, pp. 1045–1062 ; Sept. 21, pp. 1065–1081 ; Sept. 28, pp. 1085–1114 ; Oct. 5, pp. 1117–1142).

The Calibration of Extensometers. R. L. Templin. (Paper read before the American Society for Testing Materials, June 1928).

Tests of Specimens Cut from Different Parts of Structural Steel Shapes. M. O. Withey. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 29). The results are presented of tension and compression tests on specimens cut from the flanges, webs, and other parts of structural steel shapes. The

variations in strength, properties, and relationships between yield point, proportional limit, and ultimate strength, are shown.

Report of Research Committee on Yield Point in Structural Steel. (American Society for Testing Materials, June 1928, Preprint No. 25). A progress report of the Committee on a second series of tests to determine the effect of rate of application of load upon the yield point of specimens cut from structural shapes and plates.

The Plastic Flow of Metals. (Metallurgist, 1928, Sept. 28, pp. 133–134). This is a brief note (in English) of two papers, one by W. Lode which appeared as No. 303 of the " Forschungsarbeiten auf dem Gebiete des Ingenieurwesens," published by the Verein deutscher Ingenieure, the other by Sachs, which is abstracted below. Lode's work dealt with the assessment of limiting values of the stresses that may be permitted in a material subjected to various kinds of compound loading. He experimented with thin-walled tubes which could be loaded axially in tension, and at the same time subjected to known hydraulic pressures ; the walls were thus put under three-dimensional stress. Preliminary tests showed that the elastic limit was not so important as the " flow " stress, at which the material underwent a relatively large amount of deformation. It was possible to determine the flow stress as a function of the strain and the condition of loading. The observations could best be represented by the " constant energy of deformation " equation ; for copper and nickel the relation was fulfilled without exception, but in the case of iron only at those values of strain at which work-hardening occurred. It appeared that the danger of the occurrence of plastic deformation is equal in tension and torsion if the maximum shear stress in torsion is about 15 per cent. greater than in tension.

On the Derivation of a Condition of Flow. G. Sachs. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 2, pp. 734–736). The author puts forward an explanation of the phenomena observed during the distortion of crystal aggregates based on the properties of single crystals. A comparison of the tensile and torsion stresses for a constant pure shear stress in the slip planes of regular face-centred crystals gives a shear stress in torsion 15·5 per cent. higher than that in tension or compression. The results for copper, nickel, and iron published by various investigators show an average value for this difference of $12 \pm 1 \cdot 5$ per cent.

Increasing the Utility of the Bend Test. A. B. Kinzel. (Iron Age, 1928, Vol. 122, Sept. 6, pp. 575–576). The author discusses some factors involved in carrying out the bend test, and points out that the angle of bend is not a true measure of ductility. He gives particulars of a new bend extensometer which measures the extension of

the outer fibres of the metal at failure, which, when calculated against the degree of curve and thickness of specimen, gives the percentage of fibre elongation. The instrument should not be applied to the testing of ductile sheet or to material which causes the needle to rotate more than one revolution on the dial, because the approximations involved in the derived formula are not then sufficiently accurate.

On the Further Development of the Compression Test. E. Siebel and A. Pomp. (Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, 1928, Vol. 10, pp. 55–62). In a previous paper (*see* Journ. I. and S.I., 1927, No. I. p. 945) the authors described how the "barrelling" of test-pieces in the compression test could be prevented by using cone-shaped pressure surfaces. In the present paper a special contrivance for ensuring that the specimen is loaded axially is described ; by its use and by greasing the ends of the specimen in contact with the pressure surfaces it is possible to reduce the angle of the cone so that it is very nearly a flat surface. By this means the determinations become much more accurate, and curves relating the stress to the change of shape can be plotted. Other aspects dealt with are the possibility of relating the plasticity to the stress conditions at the time by means of the Mohr method of representing the stress conditions at the yield point, and also the evaluation of a measure of the plasticity from the compression diagram similar to that for the elongation in the tensile test.

Influence of the Speed of Deformation on the Course of the Flow Curves of Metals. E. Siebel and A. Pomp. (Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, 1928, Vol. 10, pp. 63–69 ; *abstract*, Metallurgist, 1928, Aug. 31, p. 127). Compression tests on various cast steels and copper showed that during deformation in the cold the resistance to deformation of the metals increased with the speed of deformation. This effect is already noticeable at low speeds, and in cast steel it leads to the raising of the yield point. At speeds of deformation such as are employed in practice, the flow curves of these materials should be about 30 per cent. higher than the static strength values. Tests on soft lead showed that above the recrystallisation temperature the curves are irregular, and the effect of the speed is increased ; this is attributed in the first place to the process of recrystallisation.

The Determination of Constants Relating to the Impact of Two Bodies. J. Ikubo and M. Hara. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 1011–1025). The authors have studied experimentally by means of a specially designed apparatus the phenomena relating to the impact of two bodies during the period of impact. The materials tested were a number of non-ferrous metals, india-rubber, and soft iron.

The Suitability of Dynamic Testing Machines for the Investigation of Plastic Deformations. J. Geller. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Oct., pp. 257–260). Consideration is given to the mathematical conditions involved in operating reversal of stress testing machines, whether of the tension-compression type or of the vibratory-torsional type. It would appear from the calculations that none of the existing types of machines for testing by reversal of stress are suitable for showing the influence of the speed of deformation on the internal friction of the material.

Experimental Study of Plastic Deformation. P. A. Wélikhoff and N. P. Stchapoff. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, June, pp. 299–311). Mild steel test-pieces were polished, etched with picric acid, and strained; certain grains and any other interesting features were then photographed. The specimens were then strained again at a higher strain and the same grains rephotographed, the process being repeated until the test-pieces broke. An apparatus is described by which very small specimens could be observed microscopically while actually under load. The authors' observations of the process of plastic deformation are recorded.

The Impact Resistance of Steels at Low Temperatures. I. F. Morrison and A. E. Cameron. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 4, pp. 533–551).

The Notch. F. László. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 16, pp. 851–856; *abstract*, Metallurgist, 1928, Oct. 26, pp. 149–150). The effect of rapid changes of section on the distribution of stresses and on the strength properties of materials is discussed.

Static Principles of Dynamic Fracture. W. Kuntze. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Oct. 20, pp. 1488–1492). Two features of fracture under alternating stresses are dealt with on static principles: the localisation of the deformation at the place of fracture, and the reduction of the rupture strength to below the yield point; the localisation of deformation is attributed to the first local deformation which, after the first stress alternations, causes a reduction of the resistance to deformation at that part to $\frac{2}{3}$ to $\frac{3}{4}$ of the yield point. After further stress alternations the resistance to deformation recovers slightly. The repeated to-and-fro motions are to be regarded as shear processes which reduce the rupture strength below the yield point. The degree of resistance to deformation after repeated loading and the reduction of the strength through shear are factors controlling the fatigue of the material.

Which Small Standard Notched-Bar Impact Test-Piece ? F. P. Fischer. (Stahl und Eisen, 1928, Vol. 48, Apr. 26, pp. 541–547; Kruppsche Monatshefte, 1928, Vol. 9, Apr., pp. 53–60; *abstract*, Metallurgist, 1928, Aug. 31, pp. 123–124). The author discusses the various single and multiple notched impact test-pieces at present in general use, and suggests that in future the Mesnager and the Charpy types of test-piece should be standardised for small and large sizes respectively, and their use in all countries adopted.

Some Effects of Heat on the Physical Properties of Steel. J. L. Cox. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 225–238). The author describes the phenomena occurring in tensile tests of steel with rising temperature, together with the appearance and effects of creep. The necessity for extreme accuracy in the determination of the proportional limit at elevated temperatures, and the attendant difficulties, are pointed out.

The Stability of Metals at Elevated Temperatures.—C. L. Clark and A. E. White. (University of Michigan, Department of Engineering Research, Bulletin No. 11, 1928). This research was undertaken for the purpose of determining what relation, if any, exists between the results obtained from short-time tensile and long-time creep tests; the factors affecting the stability of metals at high temperatures; and the mathematical relationship existing between the variables encountered in long-time testing. In regard to the first problem, it is concluded that whether or not any relation exists between these two forms of testing depends entirely on the temperature range under consideration. If the temperature employed is at or below the equi-cohesive temperature, which for plain carbon steels is 600° F. (316° C.), or higher, then a limiting creep stress will exist, and this will probably lie either at or above the proportional limit value as determined by carefully performed short-time tensile tests. If the temperature employed is above the equi-cohesive temperature, then an absolute limiting creep stress does not exist, and so there can be no relationship between the two forms of testing in this range of temperature. In this same connection, however, the author's findings show that stresses requiring periods of 10,000 hr. or so to produce rupture in this temperature range are generally of the same order of magnitude as the proportional limit values for the steels at these same temperatures. Therefore, carefully determined proportional limit values are useful in that they represent stresses requiring considerable periods of time to produce rupture. Considering the factors affecting the stability of metals at elevated temperatures, again two separate temperature ranges must be taken into account. The stability of a metal or any other substance can only be increased by increasing the strength of or removing the weakest phase present. Since the weaker phase in steel changes at a certain temperature, it is evident that the factors affecting stability must also

change at this temperature. Considering the relationship existing between the variables encountered in long-time testing, the experimental results from the expansion tests were treated mathematically to determine whether or not stress and time could be in any way related. The equation which was found to express most accurately the results was of the following type :

$$y = ax^b,$$

in which y = stress in lb. per sq. in. ; x = duration in hours ; a and b = curve constants. The metals used in the investigation were two carbon steels, with $0 \cdot 13$ and $0 \cdot 38$ per cent. C. respectively, Enduro metal, a high-chromium, low-carbon alloy, and a number of alloy steels.

Tensile Test of Steels at High Temperatures. T. Inokuty. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 791–816). The author has determined the mechanical properties of Armco iron and steels containing from $0 \cdot 1$ to $1 \cdot 5$ per cent. of carbon in the annealed condition at temperatures ranging from 20° to 1100° C., and from the results suitable forging temperatures were determined.

The Mechanical Properties at High Temperatures of Drawn Steel Wires, with Reference to the Degree of Drawing, the Working Temperature, and the Carbon Content. A. Pomp and W. Knackstedt. (Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, 1928, Vol. 10, No. 8, pp. 117–174). Four varieties of steel wire 5 mm. in diam. were used for the tests ; one was an ordinary low carbon ($0 \cdot 03$ per cent.) steel, the others were " patented " wires with carbon $0 \cdot 35$, $0 \cdot 70$, and $0 \cdot 84$ per cent. respectively. The wires were drawn down on a power-driven drawing bench until they would draw no further, the temperature of drawing varying between 20° and 300° C. The usual mechanical tests were then made on the resulting thin wires. It was found that an increase in the temperature when drawing the patented wire resulted in the raising of the tensile strength, the yield point, and particularly the elastic limit ; it would appear that drawing at 200° or 300° C. might be promising for the production of highly elastic wire.

The Practical Interpretation of Creep Data. (Metallurgist, 1928, July 27, pp. 104–106). Some results of tests made by various workers are reported, and the difficulty of interpreting them owing to the way in which the different workers' figures " spread " is discussed.

The Mechanical Properties of Cast Steel at High Temperatures. A. Pomp. (Stahl und Eisen, 1928, Vol. 48, Sept. 20, pp. 1321–1330 ; *abstract*, Foundry Trade Journal, 1928, Vol. 39, Nov. 8, pp. 341–342).

Mechanical Properties of Cast Steel at High Temperatures.
F. Körber and A. Pomp. (Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, 1928, Vol. 10, No. 6, pp. 91–105 ; Stahl und Eisen, 1928, Vol. 48, Sept. 20, pp. 1321–1330). Twelve different varieties of steel, some alloyed and some plain, from the open-hearth, Bessemer converter, and the electric furnace, were subjected to comparative tests in the temperature range 20° to 500° C. The usual mechanical tests were made, and the results are tabulated and recorded graphically. In an appendix the influence of the shape of the test-piece and of the location of the test-bar in the casting on the results of the notched-bar test are investigated ; the marked influence of the manner in which the test-piece is taken, particularly in cast steel, is demonstrated.

High Tensile Material for Boilers and Tanks at High Working Temperatures. P. Prömper and E. Pohl. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, June, pp. 785–793). The article describes tests of various alloy steels with a view to discovering their suitability for the construction of high-pressure boilers, and other vessels subjected to pressure at high temperatures. Two kinds of steel plates were tested, one being a low-vanadium, the other a low-molybdenum steel. The compositions were :

	C.	Si.	Mn.	P.	S.	V.	Mo.
Vanadium steel (per cent.)	0·19	0·00	0·47	0·015	0·028	0·19	0·00
Molybdenum steel (per cent.)	0·15	0·00	0·50	0·020	0·017	0·00	0·34

The vanadium steel plate was 32 mm. thick and the molybdenum plate was 23 mm. thick. The results of the tests at temperatures ranging from 20° up to 500° C. are given in very full detail. In general, the vanadium steel plate, annealed, had at 20° C. an elastic limit of 30 kg. per sq. mm. and an elongation of 26 per cent. At 500° the corresponding values were 20 kg. per sq. mm. and 41·5 per cent. The molybdenum steel plate at 20° C. had an elastic limit of 29·15 kg. per sq. mm. and an elongation of 25·5 per cent. At 500° the corresponding values were 22·1 kg. per sq. mm. and 25·5 per cent. Tests were also made on water-gas welded joints of the same plates. The elastic limits were approximately the same as above, and the elongation for the vanadium steel plate at 500° was 9·5, and for the molybdenum steel plate 6·0 per cent. These elastic limits are about 70 to 100 per cent. higher than those of plain carbon steel with carbon from 0·15 to 0·31 per cent. The alloy steels can be welded and hot- and cold-worked with the same facility as the plain carbon steel of the same carbon content. The vanadium steel is specially resistant to corrosion.

Notes on Behaviour of Basic Open-Hearth Steel Plates. E. Pohl. (Stahl und Eisen, 1928, Vol. 48, May 17, pp. 649-656 ; *abstract*,

1928—ii.   **2 D**

Metallurgist, 1928, Aug. 31, pp. 119–120). The investigation is mainly concerned with the effect of high temperatures on the tensile properties of basic open-hearth boiler plates. For the tests a plate was rolled, of length 33 ft., width 8 ft. 8 in., and thickness about $\frac{7}{8}$ in. (23 mm.), from a 5-ton slab. The average analysis was C = 0·27, Si = 0·00, Mn = 0·60, P = 0·035, S = 0·031, Cu = 0·16 per cent., and the tensile strength was 30 tons per sq. in. The elastic limit, yield point, elongation, reduction of area, and notch toughness were all determined at temperatures ranging from 20° to 500° C. In addition, specimens were stretched at various temperatures up to 500° C., and the effect on the material was studied both at the temperature at which the stretching had taken place and at room temperature. In specimens stretched at blue heat (between 200° to 300°) there is a considerable falling off in the impact resistance as compared with impact test results obtained at temperatures below and above that range, more particularly if the cold-working stresses have exceeded the elastic limit, and overstressed material becomes dangerously brittle in the blue-heat range. In high-pressure boilers, therefore, it is safer to work at temperatures of 350° to 400° than within the range 200° to 300°, since, though the yield point may be 25 per cent. lower, the value of the impact resistance is double at the higher temperature.

Behaviour of Steel under Prolonged Stress at High Temperatures. A. Pomp. (Chemische Fabrik, 1928, Feb. 1, pp. 53–54). The author reviews the work of other investigators on the creep of steel at high temperatures. The necessity of determining permanent strength of steels for high-pressure work at high temperatures is emphasised. Permanent strength is defined as the highest load that can be withstood at any given temperature without increasing the length after 3 to 6 hr. by more than 0·001 per cent. per hr.

The Properties of Materials for Use at High Temperatures, with Special Reference to Boilers for Superheated Steam. R. G. C. Batson. (Paper read before the Engineering Conference of the Institution of Civil Engineers, 1928 : Iron and Coal Trades Review, 1928, Vol. 117, Aug. 10, pp. 197–198). The results expected from 0·10 and 0·17 per cent. carbon steels used for boiler and superheater tubes, and from 0·23 per cent. carbon steel used for superheater and steam drums, are tabulated. The values indicate the extremely rapid decrease in the limiting creep strength of boiler tube steels as the temperature is raised above 400° C. At a temperature of 525° C. the actual working stress in the tubes may be equal to the limiting creep stress.

There is evidence that failure by intercrystalline cracking may occur with boiler tube steel at temperatures of about 600° to 650° C. Further, this steel readily oxidises in the presence of air above 570° C. If boiler pressures and temperatures are to be raised much above their present limits, materials other than those now employed must be used.

For this purpose a material with a limiting creep stress of about 13 tons per sq. in. at 500° C. is required, with good ductility at normal temperature. It is possible to obtain materials that will meet the requirements for increased steam pressures and temperatures, but as they involve the use of expensive alloys, their application at present is extremely limited.

Testing of Materials at Elevated Temperatures. P. G. McVetty. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 36). The author discusses the general subject of materials testing as a basis for choice of materials and working stresses to be used in applications at elevated temperatures. The short-time and long-time tension tests are discussed in detail, including test methods, possibility of errors, and interpretation of results. The subject of accelerated tests is taken up, with a discussion of the value of such tests as a basis for design.

The Seizing of Metals at High Temperatures. N. L. Mochel. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 37). The author describes a machine for the testing of various metals to determine whether such materials will operate in contact with each other without seizing. Results of preliminary tests at 750° F. on a number of metals are given.

Influence of Inhibitors and Accelerators on Corrosion Fatigue of Metals. F. N. Speller, I. B. McCorkle, and P. F. Mumma. (Paper read before the American Society for Testing Materials, June 1928).

Some Factors Involved in Corrosion and Corrosion Fatigue of Metals. D. J. McAdam, jun. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 41). Part I. of the paper gives a brief résumé of previous work, an outline of the investigation, and a description of materials and methods. A variety of carbon steels and alloy steels, including stainless iron, were used. The effects of three kinds of water are discussed. The investigation was carried out by " prior-corrosion fatigue " tests, in which the specimens were first subjected to simultaneous corrosion and cyclic stress below the corrosion-fatigue limit, and then were subjected to fatigue test in air. The fatigue limit obtained in the second stage is used as a criterion of the effect of corrosion. Results of these fatigue tests are presented in ordinary stress-cycle graphs. From the fatigue limits obtained from these, three other types of graphs are derived to illustrate the effect of cyclic stress-range, time, and number of cycles. Part II. discusses the effect of varying cyclic stress-range, with constant time and number of cycles. Among the subjects discussed are notching limit, notch-depth limitation, corrosion-fatigue limit, stress-concentration ratio, and effect of electrochemical and physical properties on the behaviour

of metals under simultaneous corrosion and fatigue stress. Part III. discusses the effect of time and number of cycles on penetration of metal under corrosion. Part IV. discusses the effect of diameter or thickness of specimen on the corrosion-fatigue limit. Part V. deals with torsional corrosion-fatigue. Corrosion-fatigue limits obtained in this way are compared with limits obtained by the rotating cantilever method.

The Change in Tensile Strength Due to Ageing of Cold-Drawn Iron and Steel. L. B. Pfeil. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 167).

Some Properties of Cold-Drawn and of Heat-Treated Steel Wire. S. H. Rees. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 195).

Contribution to the Study of the Cold-Drawing of Mild Steel. R. Giraud. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Apr., pp. 175–194 ; May, pp. 235–246). In the first instalment the author gives the details and results of tests made to determine the mechanical properties of cold-drawn mild steels, indicating the various effects caused by variations in the speed of drawing, in the reduction of the section, in the number of passes, and in the lubricant used. The microstructures of the test-pieces are illustrated. The second instalment deals with the force required for drawing the metal, and the manner of its variation with changes in the various factors enumerated above.

Tests of Metal in Cold-Pressed Tubes. R. W. Miller. (Heat Treating and Forging, 1928, Vol. 14, Oct., pp. 1162–1163). Tests on cold-pressed tubes, 3 m. long by 160 mm. sq. internal area, made of 15 mm. steel plate, showed that their production by that method resulted in a satisfactory article ; if the normal properties of the metal in its original state were desirable they could be obtained by a subsequent anneal at 850° C. after the completion and welding of the tube.

Cold and Hot Working of Metals. W. Rosenhain. (Metallurgist, 1928, Oct. 26, pp. 152–153). The theory of the processes by which metals undergo deformation is discussed.

The Influence of Cold-Rolling and Annealing at Various Temperatures on the Strength Properties and Grain of Thin Sheets. E. Marke. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 177–183). The sheets tested were of high quality, of the following composition : carbon 0·06, manganese 0·52, phosphorus 0·023, and sulphur 0·029 to 0·038 per cent. The initial thicknesses before cold-rolling were 0·9, 1·1, and 2·5 mm. Each set of sheets was subjected to cold-

rolling, the thickness in two cases being reduced by 2·5 per cent. and in the third (the thickest sheets) by 6·9 per cent.; in a second cold-rolling they were reduced by 2·8 per cent., and in a third by 30 to 38 per cent. Annealing followed each cold-rolling operation. It was noted that with an increasing degree of cold-rolling the tensile strength and the Brinell hardness were increased, and the Erichsen value and elongation fell off. The effect of cold-rolling is removed by suitable annealing. A high degree of cold-rolling followed by annealing at 580° gives a very fine structure, but the annealing period should be two to three times as long as when annealing above the Ac_3 point. If cold-worked within the critical range, an annealing at 680° to 800° produces a coarse crystalline structure, but at above 900° it becomes very fine.

Influence of Cold-Rolling and Subsequent Annealing on the Strength and Structure of Special Quality Thin Steel Sheets. E. Marke. (Iron and Coal Trades Review, 1928, Vol. 117, Oct. 12, pp. 541; Oct. 19, pp. 579–580). A translation of the above paper.

The Cold-Working Effect in Carbon Steels in Relation to Temperature, Time, and Structure. F. Sauerwald, L. Michalsky, R. Kraiczek, and G. Neuendorff. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 717–720). Impact compression tests were made on carbon steels below the pearlite point and in the γ range, and by measuring the increase in hardness the amount of the cold-work effect was determined. The tests were carried out under conditions which enabled the observer to note the line of demarcation between deformation in the cold and in the hot state. The speed of deformation is an important factor in this connection. In the case of moderately hard steels the capacity for deformation gives an excellent criterion for differentiating between cold and hot deformation. A fairly rapid deformation of carbon steels below the pearlite point always produces a cold-working effect, which remains even after slow cooling of the material. At higher temperatures the maximum cold-working effect is produced by rapid deformation rather than by slow deformation; but the γ mixed crystals with 0·9 per cent. carbon show no cold-working effect under static or dynamic deformation at 100° above the pearlite point. The fracturing of the cementite crystals lowers the resistance to deformation.

The Change of Elastic Constant in Metals caused by Cold-Working. K. Honda and R. Yamada. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 723–741). The change of Young's modulus of elasticity due to cold-working was measured for iron, steel, copper, aluminium, and brass. The elastic constant is decreased by cold-working, the amount of decrease being about 3 per cent. in the case of single crystals and 6 to 10 per cent. in the case of polycrystals.

Qualities of Cold-Rolled Shafting. J. R. Miller. (Iron Age, 1928, Vol. 122, Sept. 13, p. 637). The comparative qualities of cold-rolled shafting and cold-drawn steel are briefly discussed, and typical compositions of steel for cold-working are tabulated.

Hardness and its Relation to the Cold-Working and Machining Properties of Metals.—Part II. H. O'Neill. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 109–156). (Part I. of this report appeared in the Carnegie Scholarship Memoirs, 1926, Vol. 15, pp. 233–279). Section I. deals with the scratch test and its applications ; the nature of the deformation by scratching and scratching by a conical or V-sectioned tool are discussed, a sclerometer using a 1-mm. hemispherical diamond is described, and tests on hardened steel with rough and smooth diamonds and scratch tests on aggregates, on annealed single crystals of ferrite and aluminium, and on cold-worked single crystals of ferrite are recorded. Section II. contains a discussion of hardness and machinability, particular reference being made to the relationship between those properties in the case of brasses. Section III. is devoted to the Brinell test and its relation to tensile and compression tests. Section IV. gives an historical survey of the idea of hardness, which is followed by a sub-section on the measurement of the diameter of immersion of a diamond as a method of hardness testing.

Apparatus and Methods for Measurement of the Hertzian Hardness. R. Esnault-Pelterie. (Paper read before the British Section of Société des Ingénieurs Civils de France : Engineer, 1928, Vol. 146, Aug. 17, pp. 180–181 ; Aug. 24, pp. 196–197 ; Aug. 31. pp. 220–222). An English version of two papers which appeared originally in French (see Journ. I. and S.I., 1927, No. I. p. 931, and 1927, No. II. p. 612).

A New Apparatus for the Testing of Metals, '' The Sclerograph.'' (Arts et Métiers, 1928, Vol. 81, May, pp. 197–199). The hardness of samples is tested in this apparatus by the height of rebound of a movable part. A rod carrying a specially hardened ball at its lower end is capable of movement within an outer slotted vertical tube. The top of this tube carries a cage which restrains three balls from dropping into an inverted cone-shaped space formed in the top of the tube. Near the top of the movable rod is a collar, so adjusted that it displaces the cage just as the ball at the lower end of the rod strikes the work under test. As the rod rebounds, the balls, which have now dropped into the cone-shaped space, offer no resistance, but as the rod tends to fall again after the rebound they lock it in position and so enable the height of rebound to be read off on a scale.

Calibration of Rockwell Hardness Testing Machines. F. S. Mapes. (Paper read before the American Society for Testing Materials, June 1928).

Experiments with the Herbert Pendulum Hardness Tester when Working with Machine Tools. A. Wallichs and K. Krekeler. (Stahl und Eisen, 1928, Vol. 48, May 10, pp. 626–627 ; *abstract*, Metallurgist, 1928, Sept. 28, p. 143). Tubular test-pieces of case-hardening and heat-treated steels were work-hardened to various degrees by being turned with tools having different front rake angles under known loads. Time- and work-hardness tests were then made. Tests on the un-machined specimens showed their time- and work-hardness values to be in the order of their tensile strengths. After machining the results varied ; the time-hardness and work-hardness of the turned parts and the time-hardness of the oval impression made in carrying out the work-hardness test of the heat-treated steels all increased with increasing tensile strength, but the corresponding values for the case-hardening steels were not in the order of the tensile strengths.

The Herbert Cloudburst Hardness Testing Machine. (Engineering, 1928, Vol. 126, July 6, pp. 28–29). The theory of the cloudburst test for examining the hardness of objects and two machines for carrying it out were described by E. G. Herbert, the inventor, in the Journal of the Iron and Steel Institute, 1927, No. II. pp. 277–282. The present article describes a new machine employing the same phenomena for testing such parts as motor-car tappets, &c. The inventor has also perfected a projection microscope for examining the work after testing ; it can be used simply to examine the surfaces to determine whether any parts are too soft, or, by arranging the cloudburst machine to cause impressions spaced apart from each other (the balls falling from a predetermined height), it can be used in conjunction with specially ruled screens to ensure that the hardness of the objects under test lies within the limits specified.

Hardness Testing. H. M. German. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 343–354). The author presents some of the newer ideas regarding Brinell, Rockwell, and scleroscope hardness testing. Charts showing comparative hardness values of Brinell with Rockwell C, Rockwell B, and scleroscope, and a brief description of the Vickers and monotron hardness testing machines are given.

Relation between the Pressure and the Diameter of Impression in Hardness Test. K. Takahasi. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 843–856).

A Contribution to the Testing of Hardness. E. Franke. (Werk-stoffausschuss des Vereines deutscher Eisenhüttenleute, Report No. 102, Apr. 25, 1927 ; Kruppsche Monatshefte, 1927, Vol. 8, Nov., pp. 179–187). The author's experiments were designed to determine the re-lation between the ordinary Brinell hardness values and those obtained

with an impact machine ; in the latter a weight was allowed to fall from a given height on to the test-piece, and the imprint in the specimen formed by a ball fastened to the bottom of the falling weight was measured. The relationship of the " falling weight " hardness to the Brinell figure was found to be $1 \cdot 55$ for the 5-mm. ball and $1 \cdot 71$ for the 10-mm. ball over a wide range of height of fall. For hardness testing at higher temperatures the use of the 10-mm. ball is recommended. The scratch hardness test was also compared and was found to parallel the Brinell ; the scratch test is liable, however, to many errors, and, further, repeat results cannot be obtained by different observers with different machines.

A Note on the Hardness and Impact Resistance of Chromium-Nickel Steel. B. F. Shepherd. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 67–71). The author gives results of Izod impact, hardness, and tensile tests of chromium-nickel steel of the S.A.E. 3250 type with varying nickel and carbon contents. Higher carbon reduces resistance to impact without production of increased hardness. Tempering to 300° F. increases impact resistance without materially affecting the hardness, but best use of this type of steel is obtained with 550° F. temper.

The Self-Hardening Property of Chromium Steel. I. Obinata. (Memoirs of the Ryojun College of Engineering, 1928, Vol. 1, No. 2, pp. 145–166). The author has investigated the self-hardening property of chromium steel. The steels, which contained from 7 to 18 per cent. of chromium and from $0 \cdot 11$ to $0 \cdot 30$ per cent. of carbon, were examined in the annealed and quenched conditions. The author concludes that in the series of chromium steels which have a self-hardening property the dissociation of a carbide into another certain carbide, or merely into carbon, takes place above the Ac_1 point, though the formula is not definitely settled. The dissociation and the re-formation of the carbide take place at a comparatively rapid rate while the temperature is high, but the temperature coefficient of the reaction velocity requires a markedly large value. Therefore, the re-formation of the carbide can hardly proceed below the normal A_1 point. The lowering of the carbide change-point on cooling, which imparts the self-hardening property to the steel, is due to the retardation of the deposition of the re-formed carbide from the supersaturated solid solution ; this is caused by the viscosity of the steel, which is increased by the action of the chromium.

The Slip Interference Theory of Hardening. M. G. Corson. (Mining and Metallurgy, 1928, Vol. 9, July, pp. 304–306).

The Structure of Hardened Carbon Steel. B. D. Enlund. (Jernkontorets Annaler, 1928, pp. 374–394).

Thermal Brittleness in Metals. T. Inokuty. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 817–842). The blue brittleness of steel is discussed, and it is shown that aluminium, copper, lead, tin, and brass also show the same phenomenon.

Measurement of Brittleness. P. L. Irwin. (Paper read before the American Society for Testing Materials, June 1928). A description is given of a machine for determining brittleness of metals. It is shown that ultimate strength in cross-bending is a measure of brittleness, and a method for the removal of hydrogen brittleness is described.

An Investigation of Abrasion in Carbon Steels. M. Suzuki. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 573–638). The author has measured the relative abrasion of six hypo-eutectoid carbon steels having different carbon contents and structures with a new form of apparatus. From the investigation two laws for the relative abrasion of different steels were obtained, by means of which the amount of the relative abrasion between any two substances can be calculated if their standard abrasions be known.

The Wearing Qualities of Tyre Chains. W. H. Parker. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 33). The author describes a wear test in which the specimen is held at constant pressure against a rotating alundum grinding wheel, the surface of which is kept continuously dressed. The number of revolutions required to produce a given depth of wear is automatically recorded. The specimen used may be of almost any shape, including formed chain links. The service to which tyre chains are subjected involves the relation between impact and wear resistance, and a somewhat theoretical discussion of this relation as applied to the links of a tyre cross-chain is given. Some results of wear tests are reported. A comparison with service tests indicates that the laboratory test rates various materials in practically the same order as road tests, while giving a much greater distinction between them. The laboratory test furnishes a relatively quick means for comparing different materials and heat treatments.

Wearing Tests of 12 per Cent. Manganese Steel. J. H. Hall. (Paper read before the American Society for Testing Materials, June 1928). Wear tests were carried out in Amsler and Brinell abrasion machines, and it was found that these machines did not simulate the particular kind of wear that manganese steels successfully withstand in service—that is, abrasion associated with severe cold-working. The stone-crusher, although slow and costly to operate, is the only method giving results at all comparable with service conditions. The paper gives results of tests in such a crusher of manganese steel, plain carbon steel, nickel steel, chromium steel, and nickel-chrome steel. Manganese

steel outwore carbon steel by about 10 to 1 ; chromium decreased the wear of the pearlitic steels little if any ; nickel decreased the wear to a marked extent.

Ageing of Thermo-Elements. H. Lent and F. Kofler. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 173–176). The object of the investigation was to discover which thermo-elements would show the least loss of thermal force combined with greatest durability. Elements composed of wires were used as follows :

(1) Chronin-Konstantan ; (2) Chronin V2A-steel ; (3) Chronin NCT 3 ; (4) Chronin-Cekas ; (5) Chronin-Nickel.

The analyses of the wires were as follows :

				Nickel. %	Chromium. %	
Chronin	.	.	.	83·7	14·7	
V2A	.	.	.	8·0	15·7	
Cekas	.	.	.	59·7	11·2	2% Mn
Konstantan	.	.	.	43·0	56·3	
Nickel	.	.	.	98·90	...	
NCT3	.	.	.	17·5	37·6	0·48% Mn

These elements were tested for long periods in coke-oven gas at 850° to 950° C., and in tyre reheating furnaces fired with blast-furnace gas at temperatures of 850° to 900° ; while others were exposed for two weeks in the waste gas flue of a set of gas-fired soaking pits. The loss of thermal force, if any, was noted, and where such loss occurred, it was found after long trials that this was not due to a change in the resistance of the heated elements. The losses varied in amount, but were greatest in the case of elements exposed to coke-oven gas. The chronin-nickel elements showed no loss in thermal force, but after long exposure the metals became coarsely crystalline, and tended to brittleness.

The Improvement of the Properties of Alloys and Ageing Phenomena in Iron. G. Masing. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Sept., pp. 185–194). The author discusses the production of high-duty alloys by heat treatment, with special reference to duralumin. In making high-duty irons the conditions demand the presence of super-saturated mixed crystals and very rapid cooling from high temperatures. Iron-carbon alloys fulfil these conditions, since carbon at the pearlite point, up to about 0·04 per cent., is soluble in α-iron, but at ordinary temperatures not all. The improvements in materials quenched from above 650° are discussed.

The Specific Heat of Iron below 400° C. W. H. Dearden. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 89–108). The vacuum calorimeter was applied to the study of the variations of the specific heat of iron with temperature over the range 16°

to 400° C. The specific heat was found to rise sharply to a maximum at about 115° C. The result was shown to be in accord with abnormalities and discontinuities occurring in many other properties of iron at about the same temperature.

Development of High-Tensile Structural Steel. E. H. Schulz. (Stahl und Eisen, 1928, Vol. 48, June 28, pp. 849–853). A disadvantage attending the use of high-tensile silicon steel is its greater tendency to corrosion than that of ordinary steel. The author advocates an addition of copper to structural steel to counteract corrosive tendencies, and produces evidence to show that a copper-chromium steel has tensile properties fully equal to those of silicon steel. The analysis of the copper-chromium steel was : carbon about 0·15, silicon about 0·25, manganese about 0·80, copper 0·5 to 0·8, chromium about 0·4 per cent. For heavy sections the carbon should be about 0·18 per cent. The tensile properties for material as rolled were :

	Elastic Limit. Kg. per sq. mm.	Yield Point. Kg. per sq. mm.	Elongation. %	Reduction of Area. %
Plates, 18 mm. thick . .	37·7	53·6	22·3	50
Strips, 200 × 18 mm. . .	39·3	56·1	24·0	45
Rounds, 18 mm. diam. . .	43·0	57·5	23·0	51

The notch toughness was over 10·5 kg.-m. per sq. cm. Annealing at 830° C. raised the elastic limit by about 2 to 3 kg. per sq. mm., but did not affect the other properties. The variation in strength, as between the larger and smaller sections, was not so great as in the case of the silicon steel, which was mainly attributed to the fact that the position of the critical point at 830° was about 120° lower than that of silicon steel. Teeming and rolling presented no difficulties. Thirty days' exposure to 1 per cent. sulphuric acid showed that the copper-chromium steel was about five times as resistant to the acid attack as the silicon steel.

On the Development of High-Duty Structural Steel. Koppenberg. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, June 30, pp. 918–920). The properties of nickel steel, carbon steel, low-silicon carbon steel, " St 48 " steel (carbon 0·25 to 0·35, manganese 0·5 to 0·7 per cent.) produced by the Mitteldeutsche Stahlwerke, and silicon steel are described.

High-Strength Steel for Modern Bridges. L. S. Moisseiff. **Manufacture of Acid Open-Hearth Steel for Suspension Cables.** H. C. Boynton. **Drawn Wire and its Heat Treatment.** A. V. de Forest. **Silicon Structural Steel for Bridge Construction.** H. T. Morris.

(Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 941–960). These four papers constitute a symposium on the manufacture and use of high-strength structural steel for bridges. High-strength steels for bridges were first introduced in America in the form of drawn wire for cables. Nickel steel has since been used for bridge members. Mayari steel has been used and also silicon steel. It is stated that acid open-hearth steel is superior for suspension cables, based on practical experience and the service it has given, in addition to the usual tests. The manufacture of wire used for bridge cables is described, and the suitability of heat-treated parts for service covering a period of many years is discussed.

Tests of Structural Members for Sydney Harbour Bridge. (Engineering, 1928, Vol. 125, June 8, pp. 697–698, and Plates). The 1250-ton universal testing machine used for the tests has been described earlier (*see* Journ. I. and S.I., 1926, No. II. p. 637). The present article describes the arrangement of its housing at Messrs. Dorman, Long & Co., Ltd., Britannia Works, Middlesbrough. Photographs of models of various structural parts under test are reproduced, but very little data concerning the tests are given.

Alloy Bridge Steel Sixty Years Old. E. E. Thum. (Iron Age, 1928, Vol. 122, Sept. 20, pp. 683–686, 733). The Eads Bridge over the Mississippi River at St. Louis was the first American bridge in which steel was used for the main members. The arch ribs were constructed of chromium steel with the average composition of carbon 0·79 and chromium 0·61 per cent. The difficulties encountered in the fabrication and erection of the bridge are reviewed. An examination of the bridge was made 28 years ago and again last year, but aside from a few minor details no evidence of overstrain, such as cracking of paint films, could be discovered. No traces of interior or exterior corrosion were noted.

Steel for Shipbuilding. Sir W. J. Berry. (Paper read before the Engineering Conference of the Institution of Civil Engineers, 1928 : Iron and Coal Trades Review, 1928, Vol. 116, June 15, pp. 900–901). The first ships to be built wholly of steel for the Royal Navy were ordered in 1875, and two years later Lloyd's Registry formally sanctioned the use of mild steel for mercantile vessels and issued their standard tests. Lloyd's tests were similar to the Admiralty tests, except that the ultimate strength called for was 27 to 31 tons per sq. in. instead of 26 to 30. In 1898 the Admiralty began to adopt what since became known as H.T. quality, in which, in association with a tensile strength of 33 to 38 tons per sq. in., a yield point of 20 tons was stipulated.

H.S.T. steel (used for submarines) was a development of the same material, as was also H.H.T. (for destroyers), in which the ultimate

strength was further increased to 37 to 43 tons per sq. in. A steel has since been evolved for Admiralty use (now widely known as D quality) in which a proportional limit of 17 to 20 tons per sq. in. is associated with an ultimate strength of 37 to 43 tons per sq. in. As regards chemical composition, advantage is taken of the beneficial effect of increased percentages of manganese, in raising the proportional range without detracting from ductility. A fairly representative composition would be carbon $0\cdot33$, manganese $1\cdot1$ to $1\cdot4$, silicon $0\cdot12$, sulphur and phosphorus being kept to about $0\cdot3$ or $0\cdot4$ per cent. In 1925 Lloyd's sanctioned the use of steels similar in character to that adopted by the Admiralty, but with the ultimate strength kept to a lower figure and the proportional limit lowered to 15 tons per sq. in.

Types of Failure of Steel. R. Job. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 239–247). The various types of failure occurring in steel parts, such as rails and axles, are illustrated.

Locomotive Part Failures and their Microstructure. F. H. Williams. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 211–224). The author presents the results of a microscopic examination of different types of failure met with in locomotive parts. A portion of the paper is devoted to a study of welded parts of forgings used in locomotive construction.

Locomotive Boiler with Plates of Nickel Steel. (Aciers Spéciaux, 1928, Vol. 3, Oct., pp. 202–204). The article describes the boilers fitted to the new Pacific and Mikado type locomotives of the Canadian Pacific Railway. The problem was to increase the steam pressure without increasing very much the weight; this was attained by the use of a nickel steel with $2\cdot75$ to $3\cdot25$ per cent. of nickel, $0\cdot20$ per cent. max. of carbon, and $0\cdot4$ to $0\cdot8$ per cent. of manganese. The specifications of the old and new types of engine are compared, and the mechanical properties of the steel for the new boilers are reviewed.

Metallurgy and the Construction of Boilers. G. Charpy. (Génie Civil, 1928, Vol. 92, May 26, pp. 507–510). After a very brief reference to the manufacture of seamless headers by forging them on a mandrel the author discusses the properties of boiler-plate steel, mechanical tests, heat treatment, and its effects on the properties of the boiler-plate material.

Notes Concerning Fractured Boiler Plates. G. Ness and D. A. MacCallum. (Journal of the West of Scotland Iron and Steel Institute, Session 1927–28, Vol. 35, pp. 101–109). The experience of the authors is that all the defects hitherto met by them in practice can be traced to purely mechanical causes as the origin of the fractures. A number of examples of boiler-plate fractures are submitted.

Blading Metals in Modern Steam Turbines. A. Bodmer. (World Power, 1928, Vol. 10, July, pp. 41–47; Aug., pp. 159–163; Blast-Furnace and Steel Plant, 1928, Vol. 16, Sept., pp. 1211–1215; Oct., pp. 1337–1340; Chaleur et Industrie, 1928, Vol. 9, Apr., pp. 163–181; May, pp. 239–244). A review of the progress made in the development of suitable materials for turbine blades, both ferrous and non-ferrous. The effects of corrosion and erosion are described, and the characteristics of various metals are noted.

Stainless Iron for Naval Aircraft. E. Joyce. (Iron Age, 1928, Vol. 122, Sept. 13, pp. 627–630). The results are presented of an investigation carried out at the Naval Aircraft Factory, Philadelphia, to ascertain the suitability of stainless iron for naval aircraft construction. Two types were selected for investigation, having the following composition :

	C.	Mn.	P.	S.	Si.	Cr.	Ni.
A (per cent.) . .	0·10	0·42	0·017	0·018	0·23	12·3	0·19
B (per cent.) . .	0·04	0·22	0·016	0·016	0·33	13·4	0·13

The results of tensile, bend, and corrosion tests are tabulated. The results of the tests indicate that attention should be given to the heat-treatment temperatures used in order to bring out the maximum resistance to corrosion of these alloys. The relationship of the tempering temperature to resistance to corrosion was not studied as thoroughly as desirable, but enough work was done to indicate a decided decrease in the rate of corrosion with decrease in tempering temperature. The results also indicate that the tensile properties of these two types of material in the annealed condition are considerably better than those of mild steel, and that the ultimate strength of normalised stock exceeds that of normalised medium carbon steel.

Steel Requirements of the Aircraft Industry. H. J. French. (Paper read before the American Iron and Steel Institute, Oct. 1928). The author discusses the general technical requirements for steels used in the aircraft industry. Typical steels are tabulated and their special applications are shown.

British and American Automotive Steels. J. W. Urquhart. (Blast-Furnace and Steel Plant, 1928, Vol. 16, July, pp. 906–908; Aug., pp. 1027–1029; Heat Treating and Forging, 1928, Vol. 14, June, pp. 610–612; July, pp. 751–753). The types of steels used in British and American motor manufacturing practice are compared; those used in the U.S.A. are less difficult to heat-treat. The methods in use at the Ford Works are particularly quoted.

Note on the Inverse Segregation Observed in Certain Rails. A. Portevin. (Revue Universelle des Mines, 1928, Vol. 18, June 1,

pp. 205–207). The author describes the inverse segregation observed in a bar of semi-hard steel 80 mm. in diam. He explains its occurrence by supposing the ingot to have been rolled while the interior was not completely solid but was also not entirely liquid—that is, while its temperature lay between the solidus and liquidus. The solid would be purer metal and the liquid more impure ; on rolling, the pure " sponge " in the centre would be compressed together and the impure liquid steel would be forced into the outer parts of the ingot.

Surface Fissures in Rail Treads. (Metallurgist, 1928, June 29, pp. 91–92 ; July 27, pp. 99–101). An English version of a paper by H. Viteaux (*see* Journ. I. and S.I., 1928, No. I. p. 907).

Concerning Rail Tread Fissures. (Metallurgist, 1928, Aug. 31, pp. 127–128). Abstract in English of Sabouret's criticism of Viteaux's work referred to above, and the latter's reply.

The Testing of Colliery Wire Ropes. J. O. Cooke. (Colliery Engineering, 1928, Vol. 5, Aug., pp. 320–323). The tensile, torsion, bend, hand, and wrapping tests are dealt with, and the relative values of the different tests are briefly discussed.

Stresses in Ropes and their Examination. H. Herbst. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, Mar. 10, pp. 345–349). *Abstract,* **Winding Ropes for Mines** (Metallurgist, 1928, Sept. 28, pp. 140–141).

The Causes of Failure of Wrought Iron Chains. H. J. Gough and A. J. Murphy. (Department of Scientific and Industrial Research : Engineering Research ; Special Report No. 3, 1928). *See* Journ. I. and S.I., 1928, No. I. p. 896.

Numerous Uses for Bessemer Steel. J. R. Miller. (Iron Age, 1928, Vol. 122, Sept. 27, pp. 765–766). The qualities which give acid Bessemer steel value for certain definite uses are machinability, weldability, and stiffness. Its superiority for the manufacture of screw stock, pipes, bolts, and implement bars is pointed out.

The Testing of Castings. (Metallurgist, 1928, July 27, pp. 97–98). Some of the difficulties of obtaining test results which shall truly represent the properties of the castings to which they refer are discussed.

A Symposium on Steel Castings. (Discussion before the Institution of Mechanical Engineers and the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, Nov. 15, pp. 357–359). The Admiralty requirements for steel castings to withstand high pressures

and temperatures, the common types of failures met with, and the X-ray examination of castings are discussed.

Test Specimens from Steel Castings. (Heat Treating and Forging, 1928, Vol. 14, Oct., pp. 1178–1180). The difficulties attending the proper preparation of coupons for obtaining test-pieces representing steel castings are discussed.

Steel Castings for Severe Service. J. H. Hall. (Paper read before the Institute of British Foundrymen : Foundry Trade Journal, 1928, Vol. 39, July 5, pp. 4–6). A discussion of recent American practice in the development of steel castings to meet severe service conditions. Probably the greatest advance in the manufacture of steel castings has been made in the field of heat-treated castings of high strength and toughness for resisting heavy stresses. In some cases the castings are heat-treated by quenching in water or oil and tempering, in others they are normalised and tempered. The range of analysis of steel of this type is as follows : C 0·20 to 0·40 ; Si 0·20 to 0·50 ; and Mn 1·10 to 2·00 per cent. The range of properties obtained by heat treatment of this type of steel is shown. In addition to the manganese, vanadium in amounts up to 0·30 per cent. or molybdenum up to 0·50 per cent. are sometimes used.

General Characteristics of Alloy Steel Castings. J. W. Frank. (Paper read before the American Foundrymen's Association, May 1928). Manganese steel, nickel steel, nickel-chromium steel, chromium steel, molybdenum steel, and chromium-vanadium steel are briefly discussed, and their chief applications are pointed out.

The Geometry, Wear, and Testing of Safety-Razor Blade Edges. J. F. Kayser. (Engineer, 1928, Vol. 145, June 8, pp. 621–623). The author discusses the types of cutting edge found among a variety of makes of safety-razors, the " work " done in shaving, the composition and microstructure, the wear of safety-razor blades, the use of the microscope to control production, and the testing of safety-razor blades.

Safety-Razor Blades. H. A. Curran. (Engineer, 1928, Vol. 146, July 6, pp. 20–21). A commentary on the above paper by Kayser. The author discusses the mounting of razor blades and their polishing and etching for micro-examination, and the grinding of razors. He shows micrographs demonstrating the structural differences that may be found in two razors from one batch which gave equally good shaving results, and discusses the form of edge likely to prove most satisfactory in use.

The Strength of Hexagon Nuts of Less than Standard Size for Bright Steel Bolts. C. Jakeman. (Department of Scientific and Industrial Research, Engineering Research, Special Report No. 7, 1928).

Low-Percentage Alloys of Titanium with Iron. H. Mathesius. (Stahl und Eisen, 1928, Vol. 48, June 28, pp. 853–858). Titanium as an alloy metal or deoxidiser has generally been used with steels containing up to 0·6 per cent. carbon, and the results are so variable that no clear judgment as to the influence of titanium can be formed. The author has taken for his experiments very pure steels made in the Krupp Kryptol furnace, and containing carbon 0·05 to 0·09, silicon 0·3 to 0·7, manganese 0·23 to 0·41, phosphorus 0·007 to 0·023, sulphur trace, and titanium 0·38 to 3·21 per cent. These low-carbon titanium steels all showed improved properties as compared with ordinary steels. In general, the segregation phenomena were diminished, the elastic limit was raised to about 80 per cent. of the yield point, and the resistance to wear and the notch toughness were both increased.

Medium Carbon Pearlitic Manganese Steels. J. Strauss. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 1–26). The author discusses the metallurgical and mechanical characteristics of steel with 0·30 to 0·50 per cent. of carbon and 1·00 to 2·00 per cent. of manganese. In the higher ranges of strength and hardness the impact resistance is lower than for some other alloy steels. In heavy sections the manganese steels show very good resistance to impact, but do not harden deeply and have elastic ratios that are slightly low ; the latter defect becomes of serious magnitude in sections above 4 in. Temper-brittleness is displayed by some of these steels, but may be effectively reduced, as in chromium-nickel steels, by proper attention to manufacturing methods. In these steels, as cast, coarse dendritic formations are prone to occur in heavy sections if careful practice is not followed, but, with attention to details, exceptionally good mechanical properties are obtained, equal or superior to those of many other alloy steels. Segregation in steels containing about 2 per cent. of manganese has been noted in more than one case to be opposite to that generally found in other simple structural steels—namely, elements other than iron concentrating near the surface rather than near the centre of ingots and bars. A selected bibliography of twenty-five references to literature on the subject is appended to the paper.

A New Free-Cutting Case-Hardening Steel. (Machinery, London, 1928, Vol. 32, May 17, pp. 213–214). The results are given of tests of samples of a new mild steel known as Jalcase.

Molybdenum Steels. F. W. Rowe. (Iron and Steel Industry, 1928, Vol. 1, Aug., pp. 339–341). The properties of molybdenum steels are reviewed.

The Principal Special Steels and their Uses. L. Persoz. (Aciers Spéciaux, 1928, Vol. 3, Mar., pp. 112–121). The author deals largely with tungsten steels with various other alloying elements ; he discusses

2 E

·their properties and uses. He gives brief notes as to composition and properties of the stellite group of alloys, and includes a résumé in which the principal alloy steels, their characteristics, their uses, and their proximate analyses are tabulated.

Flakes in Chromium Steel. W. Aichholzer. (Stahl und Eisen, 1928, Vol. 48, Sept. 20, pp. 1332–1333). Flakes occur most frequently in the class of chromium steels containing 1 per cent. carbon and 1 to 3 per cent. chromium. In steels with low carbon and chromium not above 1·5 per cent., and in high-carbon high-chromium steels flakes are entirely absent. An examination of high carbon steels with 1 to 3 per cent. chromium, both in the worked and the unworked state, showed the presence of hair-cracks either isolated or in groups, each crack corresponding to a flake. The structure in such cases was abnormal, showing that there was some relation between the structure and the occurrence of flakes. Steel containing flakes always showed strong segregation of carbides in the neighbourhood of the flakes, and in these spots both carbon and chromium varied considerably from the average content of these elements. Due to the different concentrations of carbon and chromium, unequal stresses occurred on cooling, and it may be assumed that these caused heat-cracks. Tensile tests at red heat and at room temperature confirmed this view.

The Effect of Oxygen on Iron and Steel. (Metallurgist, 1928, Aug. 31, pp. 116–118 ; Sept. 28, pp. 130–132 ; Oct. 26, pp. 147–149). A review of the work of various investigators.

Manganese, the Ores and the Metal; with an Account of the History and Production of Ferro-Manganese. Sir R. Hadfield. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 4, pp. 1–92. *See* Journ. I. and S.I., 1927, No. I. p. 211).

Low-Carbon Alloys of Iron and Manganese. Sir R. Hadfield. (Proceedings of the Second Empire Mining and Metallurgical Congress, Canada, 1927, Part 4, pp. 93–162. *See* Journ. I. and S.I., 1927, No. I. p. 297).

Influence of the Structure '' As Cast '' upon Manufacturing and Qualities of Some Alloyed, especially High-Speed Steels. F. Rapatz. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 1009–1022). The present paper is a continuation of the researches of Oberhoffer, Daeves, and Rapatz. It is pointed out that a great many steels, especially high-speed and high-chromium steels, contain ledeburite, a constituent corresponding to the eutectic of pig iron, and that these steels metallographically are pig iron. It is shown that there is great variation in grain-size in different parts of an ingot,

due to different rates of solidification. It is difficult to forge a piece of steel of large section so as to break up large grains once they have formed during the solidification of the metal. The melting point of the eutectic corresponding to the ledeburite is only slightly altered by chromium (up to 14 per cent.), whereas in high-speed steels this point rises up to about 2370° F. (1300° C.). Heat treatment below these temperatures does not change the size of the ledeburite carbide. It then becomes a problem of using small ingots with fine grain-size with less forging, or using larger ingots with larger grain-size and a greater amount of forging.

Alloying Elements in Tool Steel. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 639–641). The general effects of the various elements entering into the alloy tool steels and the manner in which they combine in the metal are discussed.

On the Nature and Application of the Principal Types of Tool Steel. W. H. Wills. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Sept., pp. 363–376). The many brands of tool steels on the market may be broadly divided into five types—carbon and carbon-vanadium, oil-hardening, high-carbon low-tungsten, hot die, and high-speed steels. The structure and physical properties of each type are discussed from a practical standpoint.

Tungsten Carbide—a New Tool Material. S. L. Hoyt. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Nov., pp. 695–718). The use of tungsten carbide as a tool material is described. In tool form it has a Brinell hardness of over 2000 and is capable of scratching sapphire. The addition of cobalt improves the strength of the material. On cast iron and steel the carbide tools are shown to be greatly superior to high-speed steel and capable of sustaining cutting speeds several times higher than those commonly used. The trade name of the material described is Carboloy.

Influence of the Degree of Drawing and Compression on the Efficiency of High-Speed Steel Cutters. R. Hohage and R. Rollett. (Stahl und Eisen, 1928, Vol. 48, Sept. 6, pp. 1243–1247). Forging tests show that the material from which blanks for high-speed cutters and milling tools are made is improved by drawing out the bars and compressing the blanks under the hammer before manufacture into the finished tool. A definite degree of deformation by forging is, in fact, required to bring the blank to the state required to give the highest cutting efficiency.

Testing Hollow Drill Steel at Hofors, Sweden. S. F. Wollmar. (Mining and Metallurgy, 1928, Vol. 9, June, pp. 262–266).

Widia Alloy. (Iron Age, 1928, Vol. 122, Sept. 27, p. 773). This material has been developed by the Krupp Works, and its chief application is for cutting tools. Claims for the higher efficiency of Widia tools are based on the greatly increased cutting speeds while retaining the feeds and cuts usually employed with high-speed steel. Its hardness is said to be only slightly inferior to the diamond. No particulars are given of its composition.

Endurance of High-Speed Cut-Off Tools in Relation to Magnetic and Other Measurements. H. Styri. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 30). A number of standard cut-off tools, hardened in groups from different temperatures, were used in cutting off rings of high-carbon chromium steel having a Brinell hardness of about 180. The number of rings were counted for each grind. At least five grinds were made on each tool, and the average number of rings cut per grind was calculated. Magnetic and electric tests and Rockwell hardness and duroscope readings were made, and the relations between these values and the number of rings cut per grind are shown. The methods of measurement are described, and possible reasons for irregularities in results are shown.

Effects of Antimony, Arsenic, Copper, and Tin in High-Speed Steel. H. J. French and T. G. Digges. (Transactions of the American Society for Steel Treating, 1928, Vol. 13, June, pp. 919–940). The results are given of preliminary tests of high-speed steels of the low-tungsten high-vanadium type containing up to $1 \cdot 7$ per cent. of antimony, $0 \cdot 8$ per cent. of arsenic, $1 \cdot 8$ per cent. of copper, or $1 \cdot 8$ per cent. of tin. Each of these four elements adversely affected the hot-working properties, but all the steels could be readily machined when in the annealed condition, except the steel containing about $1 \cdot 8$ per cent. of copper. Small additions of antimony, arsenic, copper, and tin, about $0 \cdot 1$ to $0 \cdot 4$ per cent., did not materially affect the grain-size of samples oil-quenched from 1290° C. Increase in copper tended to increase the grain-size, while increase in the other elements tended to reduce the grain-size.

The Rockwell hardness was not appreciably affected by the addition of antimony, arsenic, or copper when the steels were subjected to comparable heat treatments under a wide range of conditions. Additions of tin produced no appreciable effects except when the steels were oil-quenched from 1095° C. The hardness increased with increase in tin up to about $0 \cdot 57$ per cent.; further increase in tin resulted in a decrease from the maximum hardness. The effects of each of the four elements on tool performance were relatively small in rough turning and did not correspond at all to the effects observed in finish-turning tests under light cuts and high speeds. In the finish-turning tests copper produced the smallest decrease in tool life, while tin, arsenic,

and antimony, in that order, produced the greatest reduction in tool life.

The Present Position of Röntgen (X-Ray) Technique, and its Practical Application to Cast Material. M. von Schwarz. (Die Giesserei, 1928, Vol. 15, Sept. 7, pp. 883–889 ; Sept. 14, pp. 921–925). The examination of metallic objects by X-rays and the plant required are described ; the importance of the process as a manufacturing control, particularly for die-castings, is emphasised. X-ray photographs of various castings are reproduced, and the various features in the shadowgraphs are explained.

SPECIFICATIONS.

Report of Committee A2 on Wrought Iron. (American Society for Testing Materials, 1928, Preprint No. 11). A new specification for iron and steel chain is submitted to replace, when adopted, the present standard specification of the Society.

A.S.T.M. Tentative Standards 1928. (American Society for Testing Materials). This volume contains 185 tentative specifications, methods of testing, definitions of terms, and recommended practices.

British Standard Specification and Sections for Bull-Head Railway Rails. (British Engineering Standards Association, 1928, Report No. 9).

British Standard Specifications for Railway Rolling Stock Material. Part I.—Locomotive, Carriage, and Wagon Axles. (British Engineering Standards Association, 1928, Report No. 24, Part I.).

Nickel in American Forged Steels. (Aciers Spéciaux. 1928, Vol. 3, Apr., pp. 152–173). A description is given of American practice in manufacturing special steels and of the uses to which they are put. The Society of Automotive Engineers' standard specifications for special steels are listed, and the steels usually employed in the motor industry for various parts are tabulated. Special steels used in general machine parts and in naval and locomotive construction are also dealt with.

A Note on [German] Standard Specification DIN 1691. L. Schmid. (Die Giesserei, 1928, Vol. 15, July 13, pp. 669–679). The new German specification DIN 1691 covers " cast iron " ; it is reproduced here, and its various sections are discussed and explained.

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON AND STEEL.

The Incremental Permeability Method for the Magnetic Analysis of High-Speed Steel. W. B. Kouwenhoven and J. D. Tebo. (Paper read before the American Society for Testing Materials, June 1928, Preprint No. 31). The paper describes a new method of magnetic analysis in which two magnetomotive forces are used simultaneously, and the change in induction produced by the superimposed or incremental magnetomotive force in the specimen is measured. This superimposed magnetomotive force may be produced by direct or alternating current. The magnetic properties of high-speed tungsten steel bars were investigated, using this method, and data were obtained which makes it possible to differentiate between the heat treatments received by the specimens.

Report of Committee A6 on Magnetic Properties. (American Society for Testing Materials, June 1928, Preprint No. 14). A proposed standardisation of magnetic terms, units, and symbols is submitted, together with a revised method of testing the magnetic properties of iron and steel at low inductions and audio frequencies.

Note on the Effect of Repeated Stresses on the Magnetic Properties of Steel. M. F. Fischer. (Bureau of Standards Journal of Research, 1928, Vol. 1, Nov., pp. 721–732). The magnetic changes accompanying repeated stresses are not characteristic of the effect of a fatigue crack transverse to the direction of magnetisation. The similarity of the observed magnetic changes with those brought about by the removal of externally applied static stresses indicates that the observed changes may be produced by the partial relief or redistribution of initially existing internal stresses. The fact that the magnetic changes brought about by understressing are of a similar character though less in magnitude suggests that some of the beneficial effect of understressing may be due to partial stress relief.

The Origin of the Magnetism Based on the Structure of Atoms. K. Honda. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 997–1009). It is shown that the electrons revolving round the nuclei of atoms have each a magnetic moment, but cannot be magnetised by the action of the magnetic field, and therefore cannot constitute the seat of the ferro- and paramagnetism, although they give rise to the diamagnetism. According to the author, the origin of the ferro- and paramagnetism is in the revolving electrons within the nucleus itself, in which the radius of the orbits is very small and their velocity is extremely large, approaching that of light.

The Magnetisation of Single Crystals of Iron at High Temperatures.
K. Honda, H. Masumoto, and S. Kaya. (Science Reports of the
Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 111–130). The
authors have measured the magnetisation of an iron rod consisting of
a single crystal at various high temperatures by the ballistic method.
The relations between the magnetisation and the temperature for the
directions of the three principal axes are all similar to each other and
also to those for the iron rod. The variation of the saturation value
of the intensity of magnetisation in the directions of the principal
axes with the rise of temperature is also almost the same as that
in the case of the rod. The results of the experiments are ex-
plained by the molecular theory of the magnetisation of ferro-magnetic
crystals.

**Influence of a Chromium Addition on the Electric Properties of Iron-
Nickel Alloys.** P. Chevenard. (Stahl und Eisen, 1928, Vol. 48, Aug. 2,
pp. 1045–1050). For many years systematic research on iron-nickel
alloys has been carried on in the Research Laboratory of Commentry
Fourchambault and Decazeville Steelworks at Imphy, special atten-
tion having been given to the austenitic iron-nickel alloys and their
anomalies. For studying the electric properties a galvano-pyrometer
has been used ; this consists of a 3-coil galvanometer and an expansion
pyrometer fitted with the special alloy Pyros. Increasing chromium
percentages cause the resistance curve of the alloys to rise, with a
corresponding fall of the curves of the temperature coefficients. A
number of physical-chemical changes are noted also, such as a marked
fall of the magnetic point, so that alloys with over 6 per cent.
chromium are paramagnetic above room temperature ; a rapid
diminution in the intensity of the anomaly accompanying the magnetic
transformation ; at 4·35 per cent. chromium the anomaly is hardly
noticeable ; at 550°—*i.e.* in the range of the paramagnetic state—a
new anomaly X appears, the characteristics of which are described.
Nickel-chromium alloys with 8 to 10 per cent. chromium are free from
any thermal inconstancy and possess a high positive thermal force,
and being resistant to oxidation such alloys are highly suitable for the
positive parts of thermo-elements.

Uniformity, Continuity, and Magnetic Testing. A. V. de Forest.
(Paper read before the American Iron and Steel Institute, Oct. 1928).
A discussion of certain phases of the magnetic testing of steel.

Non-Destructive Detection of Flaws. E. A. Sperry. (Iron Age,
1928, Vol. 122, Nov. 15, pp. 1214–1217). **Devises Electrical Method to
Detect Flaws in Rails.** E. A. Sperry. (Iron Trade Review, 1928,
Vol. 83, Nov. 15, pp. 1244–1246, 1249). An illustrated account is
given of a method for the detection of faulty rails by means of the fall
of potential of an electrical current. Uniform distribution is secured

by using direct current, so that no matter where the flaw or irregularity exists in the interior of the rail, it is reached and its detection made possible. The main primary energising current is made to traverse the rail by means of main brushes in contact with the track. Intermediate between these brushes are three searching brushes connected to two opposed primary coils, constituting the primary of a transformer. These coils are wound oppositely and produce opposite magnetic excitation of the transformer. All variations in the primary current will be picked up by the two outer brushes and thus be neutralised completely as to their influence on the secondary. However, in passing along the track, when a fissure occurs between one end brush and the middle brush the first coil will become excited to a greater extent than the other. The transformer will become active and in the secondary will be induced half—say, the positive side— of a sine wave curve ; but in the next instant the fissure passes between the middle and the rear brushes, giving an opposite excitation to the secondary, completing the alternating wave by adding the negative side. This wave then passes to the amplifiers and may be examined as to magnitude and characteristics. Positive indication is afforded not only of the exact location of fissures, but also their size. The uniformity of potential drop which exists at all other points of the rail is interrupted at a fissure. In a sound rail, the direction of current flow is axial unless disturbed. The slightest disturbance changes this alignment of flow, and means have been found to utilise this deviation, both as to angle and magnitude of the mean axial departure, for giving an accurate interpretation of the cause, especially when all elements are magnified to be recognisable. Thus the size, characteristic, and exact location of a fissure or other flaw are accurately determined. The inspection of rails in track, by this apparatus, is carried out by means of a specially equipped car which contains a power plant, radio apparatus, and recording mechanism. The operating speed is five miles an hour or more. The power plant placed on the forward end of the platform includes a 25-H.P. gas-engine with necessary starter and auxiliaries, directly connected to a 4000-amp., 2-v. generator operating at 900 r.p.m. A paint spraying device, controlled by a relay, sprays paint against the side of the rail whenever a defect is found at any point in its length. A recording table is provided, on top of which travels a friction-driven moving strip of paper. In contact with the paper are seven pens which are actuated by the relays in circuit with the valves. Fissures located in one line of rails are indicated on the paper by three pens, and a similar set of pens record the opposite line of rails. The centre pen records location of joints. The relays are so adjusted that a short transverse line is drawn by one pen if the internal break is of small area ; two pens operate if the break is of intermediate size, and all three pens if of large area. The fissure pens are automatically thrown out of circuit when the pen for location of joints operates.

A Simple Method for Magnetising Permanent Magnets. E. Schulze. (Elektrotechnische Zeitschrift, 1928, Vol. 49, June 28, pp. 969–974). A description is given of the Beckmann method of magnetising brake magnets and other permanent magnets by means of induction current impulse generated by closing or interrupting the current of a d.c. transformer.

Cast Permanent Magnets. J. F. Kayser. (Metallurgist, 1928, Sept. 28, pp. 136–138). The composition, cost of production, and design of cast magnets of cobalt steel are discussed. The use of castings frequently makes possible the use of shapes which it would be impossible to produce economically from rolled bar.

Magnetic Properties of Perminvar. G. W. Elmen. (Journal of the Franklin Institute, 1928, Vol. 206, Sept., pp. 317–338).

The Magnetic and Electrical Properties of Cast Iron. J. H. Partridge. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 157–190). The ballistic method of testing low-permeability alloys, by placing them in a solenoid provided with a closely wound secondary coil consisting of a large number of turns, was employed. The highest magnetic induction and permeability were obtained with annealed cast iron ; the annealing appeared to be a very precarious operation, and very slow cooling through the transformation range was required. Carbon had a marked influence on the magnetic properties ; if present as nodular graphite the induction was high, while if in the form of flakes the induction was low. With a ferrite ground-mass low hysteresis loss and high permeability appeared to be fundamental properties of the material ; with a pearlite matrix the material possessed high hysteresis loss and comparatively low permeability. Graphite did not affect the hysteresis loss, but prevented the attainment of high magnetic induction, owing to the lack of magnetic continuity of the structure, which caused small demagnetising forces to act within the specimen. The precise effect of phosphorus on the magnetic properties was not established, but it appeared to have no marked effect on the permeability or induction. The addition of nickel decreased the permeability to such an extent that when 15 per cent. was present the cast iron was practically non-magnetic. Cobalt increased the permeability, remanent magnetism, and induction, the latter on account of the existence of the graphite in a very fine state. Cobalt also increased the density, but it had very little effect on the coercive force and hysteresis loss, both of which were high. Annealing increased the maximum permeability and decreased the hysteresis loss, coercive force, and remanent magnetism.

CONSTITUTION, STRUCTURE, CRYSTALLOGRAPHY.

Molecular-Theoretical Foundations for the Strength of Material Grains. A. Smekal. (Zeitschrift des Vereines deutscher Ingenieure, 1928, Vol. 72, May 19, pp. 667–673). The author puts forward a theory that there is a distinction between " ideal " and " real " crystals ; the former he holds are bodies all of whose atoms or molecules are regularly arranged on the points of definite space lattices, while the latter he assumes to contain places of looser structure, which, he suggests tentatively, entails gaps of the size of one or two atoms or molecules. He then endeavours to explain various crystal phenomena on the basis of his hypothesis.

The Inner Structure of Crystals. (Metallurgist, 1928, Aug. 31, pp. 121–122). A criticism of the paper abstracted above.

The Influence of Pearlitisation Below the Ar$_1$ Point on the Mechanical Properties of Carbon Steels. J. Orland. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 131).

The Annealing Phenomena in Hardened Steel and the Influence thereon of Silicon and Nickel. H. Birnbaum. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, July, pp. 41–47). Previous investigators—in particular, E. Maurer, K. Honda, H. Hanemann, A. Schrader, and L. Traeger—have recorded the occurrence of volume changes in annealing hardened carbon steels. The changes take place separately, at definite temperatures, and are finite, as annealing proceeds. The changes in length consist in a contraction at 100° C., an expansion at 235° C., and a second contraction at 300°. Hanemann and Traeger assume that the martensite η phase is converted at 100° into an intermediate carbide, which they term ζ, and that at 300° this splits into ferrite and cementite. These conclusions, however, require further confirmation. The present author points out that in alloy steels the lines of equilibrium will probably follow a different course from those in Hanemann and Schrader's martensite system in the case of pure carbon steels. He has therefore made two series of annealing experiments with silicon steels and nickel steels respectively. Six silicon steels were taken with silicon ranging from 0·21 to 2·19 per cent. In five of them the carbon was round about 0·75 per cent. and in the sixth, with 2·19 per cent. Si, it was 0·53 per cent. In all the silicon steels the first contraction occurred between 80° and 150°, though it was very slight in the 2·19 Si steel, which was a spring steel. Expansion set in at 250°, though in the case of the lowest silicon steel the second contraction set in at 260° before expansion had taken full effect. For all the silicon steels the temperature of the second contraction rose as

the silicon increased. Otherwise the annealing effect was the same as in carbon steels, the magnitude of the volume change depending on the carbon content. Five nickel steels with nickel ranging from $3 \cdot 56$ down to $0 \cdot 10$ per cent. and carbon from $0 \cdot 70$ to $0 \cdot 83$ per cent. were treated in the same way. The first contraction in all cases occurred between 100° and 150°, and varied in amount according to the carbon. The temperature of the second contraction was about 50° lower in the case of three of the steels, but was held to be entirely due to the silicon content which was about $0 \cdot 35$ in those three, as compared with $0 \cdot 02$ in the other two steels. Evidence was found of four phases in martensite : (1) the ε phase of Hanemann and Schrader with a maximum carbon of $0 \cdot 115$ per cent.; (2) a phase between $0 \cdot 115$ and $0 \cdot 33$ per cent. C; (3) a phase occurring from $0 \cdot 33$ per cent. C onwards; and (4) γ-iron. The observations on the decrease of hardness on annealing justified the assumption that carbon concerned in the first contraction first changed to a form corresponding to the ε phase, and on prolongation of the annealing it separated as cementite.

The Influence of Varying Strains and Annealing Temperatures on the Growth of Ferrite Crystals in Mild Steel. C. A. Edwards and T. Yokoyama. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 141).

The Structure of High-Chromium Steel. P. Schoenmaker. (Stahl und Eisen, 1928, Vol. 48, May 3, pp. 591–593). The author first discusses the effect of chromium on the critical points of a steel with which it is alloyed, and then illustrates and describes the microstructures which he obtained in a steel (carbon $0 \cdot 47$, chromium $16 \cdot 5$ per cent.) on heating it to various temperatures and quenching; the structures of the annealed steel and of the metal after melting and pouring into water are also reproduced and considered. Quenching from below 700° C. had no effect on the hardness, but as the temperature rose to 1000° C. the hardness increased rapidly (from 270 to 555 Brinell), only to drop again even more rapidly as the temperature reached 1200° C. (220 Brinell). The first increase in hardness was due to the solution of pearlite and of the double carbides; the decrease afterwards was caused by the formation of austenite.

The Electrode Potentials of Single Crystals of Iron. K. Iwise and K. Miyazaki. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 163–167). The authors have compared the electrode potential of a single iron crystal with that of iron polycrystals, and it was found that the former was far greater than the latter. In the former case the time-e.m.f. curve rose at first but soon reached a constant value, while in the case of the iron polycrystals it showed a maximum, then gradually falling to a constant value after a very long interval of time.

Conical Illumination in Microscopy. H. S. George. (Report of Committee E-4 on Metallography, American Society for Testing Materials, June 1928, Preprint 22). The method of illumination described brings out the relief of the specimen.

Metallography Simplified for Practical Uses in Shop. E. Preuss, G. Berndt, and M. von Schwarz. (Iron Trade Review, 1928, Vol. 82, June 14, pp. 1537–1539 ; June 28, pp. 1657–1658 ; Vol. 83, July 12, pp. 78–80 ; July 26, pp. 191–193 ; Aug. 9, pp. 324–325 ; Aug. 23, pp. 444–445 ; Sept. 6, pp. 572–573 ; Sept. 20, pp. 696–698). A series of articles translated from the German by R. Rimbach dealing with the preparation of specimens and the investigation of the structure of metals by macroscopic and microscopic examination.

Equilibria at High Temperatures in the System Iron-Oxygen-Carbon. R. R. Garran. (Transactions of the Faraday Society, 1928, Vol. 24, Mar., pp. 201–207).

The Macrographic Examination of Forgings. A. R. Page. (Drop Forger, 1928, Vol. 8, Nov., pp. 202–208).

Heat of Formation of Cementite. T. Watase. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 1091–1109). Cementite was prepared by electrolysing a 2 per cent. carbon steel, and its heat of combustion was measured with a bomb calorimeter. A tablet consisting of cementite and benzoic acid or sucrose was burnt in a magnesia dish placed in a bomb filled with oxygen at a 30 kg. per sq. cm. pressure. The residue of combustion consisted of Fe_3O_4 and Fe_2O_3. From the observed amount of heat evolved and the composition of the combustion residue, the heat of the reaction $Fe_3C + 3O_2 = Fe_3O_4 + CO_2$ was found to be $366 \cdot 3$ kg. cal., which is considerably less than the result obtained by Ruff. The heat of formation of cementite was calculated from the above result and was found to be $- 4 \cdot 8$ kg. cal. The methods of determination hitherto adopted by previous investigators were examined and the defects attending them are pointed out.

The Equilibrium Diagram of the Molybdenum-Carbon System. T. Takei. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 939–944).

The Equilibrium Diagram of the Iron-Iron Sulphide System. K. Miyazaki. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 877–881). The iron/iron-sulphide diagram has been determined by means of thermal analysis and electrical resistance measurement. The sulphide used in the experiment was prepared free from oxide.

The Inner Structure of Chromium Steels. E. Maurer and H. Nienhaus. (Stahl und Eisen, 1928, Vol. 48, July 26, pp. 996–1005). Many investigators of chromium steels have attempted to establish the definite composition of chromium carbides by various methods, but the authors, having collected many of the results into a table for purposes of comparison, show that the formulæ as calculated by different workers vary within wide limits. They therefore set out to determine the composition of chromium carbides by purely physical methods. By means of expansion- and magnetic-temperature curves the points of transformation in 22 chromium-iron-carbon alloys were determined, and the boundary of the γ range in alloys with carbon contents of 0·55 and 1 per cent. was observed. For chromium the lower and upper limits were 25 and 28 per cent. as compared with 17 per cent. chromium in practically carbon-free alloys. Murakami's diagram was confirmed in its main features, except the boundary line of the transformation-free alloys. The starting point of this line is not at 0 but at 17 per cent. chromium. The physical method of investigation yielded no data from which to determine the composition of the carbides or concerning the occurrence of double carbides. Not till the conclusion of the work did the authors learn the results of Westgren, Phragmén, and Negresco on the same subject. They thereupon made an X-ray examination of residues of specimens dissolved in dilute hydrochloric acid, and now accept Moissan's formulæ Cr_3C_2 and Cr_4C. Instead, however, of Ruff and Foehr's formula Cr_5C_2, they accept Cr_7C_3.

An Assumption as to the Cause of the Allotropic Changes of Iron. D. Jones. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, Aug., pp. 199–210). The author attempts to show that the transformations occurring in iron when heated and cooled are due to changes in the iron atom. The probable changes, together with their cause and mechanism, are discussed.

X-Rays and the Constituents of Stainless Steel. E. C. Bain. (Transactions of the American Society for Steel Treating, 1928, Vol. 14, July, pp. 27–50). The changes in the amounts and conditions of the crystalline phases responsible for hardness and rust-resistance in stainless steel as developed by a variety of quenching and tempering treatments have been investigated by means of X-rays. The steel used in the experiments contained chromium 17·40, carbon 0·77, manganese 0·43, silicon 0·25, and nickel 0·24 per cent. With higher quenching temperatures the corrosion resistance increases, and the hardness also, up to the point at which a persistent austenite results. Little change occurs in the properties of these steels after quenching by tempering up to 400° or 425° C. With higher tempers the corrosion resistance is injured before marked softening begins. In the case of high quenched material distinct secondary hardness is developed,

beginning at about 475° C. temper and reaching a maximum at 500° C.

All these properties are chiefly a reflection of carbide behaviour. The higher quenches dissolve more and more carbide, thereby placing the chromium in a useful form (solid solution), and the tempering action is chiefly one of re-precipitation of carbide which lessens the chromium protection. A considerable amount of submicroscopic carbide precipitation may take place without lessening the hardness, since the fine particles act as well to produce hardness and since also the martensites, very high in chromium, are not particularly hard *per se*. It may well be that there is a definite dispersion of cathodic carbide particles which encourages maximum acid attack by lessening the path of electrolytic current flow. This thought is offered as an explanation of the sharp maximum of attack for the osmondite condition. At any rate the analogous condition is produced in these steels at 500° C. just as it occurs at a much lower temperature in carbon steels. The physical state of the carbide in this condition probably represents the first formation of perfect crystallites with the statistical average size far below microscopic range.

X-Ray Investigation of the Density of Quenched Steels and the Internal Stress Existing Within Them. S. Sekito. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 679-692). The paper contains the results of an X-ray investigation of quenched carbon steels by means of the powder method. The results indicate that the decrease in density of carbon steels by quenching is due to the expansion of the space lattice. The internal stress calculated by the diffusion of the spectral lines of quenched steels is shown to be of the same order of magnitude as the tensile strength. The plane which is at right angles to the plane of maximum atomic density is subject to the greatest internal stress.

The X-Ray Investigation of the Formation of Martensite. K. Honda and S. Sekito. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 743–760). By means of X-ray analysis it was found that in quenched steel the outer layer contains a body-centred tetragonal martensite and the inner portion a body-centred cubic martensite. The former is identified with α martensite and the latter with β martensite. The mechanism of the formation of these martensites from austenite during rapid cooling is explained on the basis of the space lattice. The broadening of the spectral lines of martensites is to be attributed to a continuously varying strain of the iron lattice caused by the presence of carbon atoms in its interspaces.

The Photomicrography and Metallography of Graphite Flakes. A. L. Norbury and L. W. Bolton. (Bulletin of the British Cast Iron Research Association, 1928, No. 22, Oct., pp. 52–54). The effect of

variations in methods of polishing and photographing on the apparent size of graphite flakes, and impurities in graphite flakes are discussed. Photomicrographs of graphite flakes may represent the flakes as larger than their true size if the methods of polishing and focusing are incorrect. Burnish polishing, on the other hand, may make some flakes too small and actually cover over others. The presence of "ferrite networks" in photomicrographs of graphite flakes is not confirmed, and is shown to be due to focusing on cavities containing the remnants of graphite flakes. It was shown by chemical analysis that certain flakes contained 30 per cent. to 37 per cent. of their weight of iron.

The Constitution of the Alloys of Aluminium with Copper, Silicon, and Iron. A. G. C. Gwyer, H. W. L. Phillips, and L. Mann. (Paper read before the Institute of Metals, Oct. 1928). After a brief summary of recent work on the binary alloys of aluminium with copper, silicon, and iron, the constitution and structure of part of the ternary systems aluminium-copper-silicon and aluminium-copper-iron are considered. The structure and constitution of certain of the quaternary alloys of aluminium with copper, iron, and silicon are also considered.

Definite Procedure Required in Etching Iron and Steel. H. H. Shepherd. (Foundry, 1928, Vol. 56, Oct. 1, pp. 785–788). A discussion of etching reagents and methods used in etching iron and steel specimens for microscopical examination.

Monocrystalline Metals. M. Privault. (Revue Générale des Sciences, 1928, Vol. 39, June 30, pp. 363–369). The preparation of single crystals of metals may be carried out according to three broad methods : (i) Solidification of the metal from the liquid phase ; (ii) solidification from a gaseous compound which is decomposed by heat ; (iii) transformation from a multicrystalline ingot directly to a single crystal by distorting it suitably and annealing it. The study of the crystals so obtained shows that deformations to which they may be subjected are due to the sliding of metallic planes upon each other parallel to certain definite crystalline planes. Their electric properties show marked anisotropy ; their thermoelectric power follows fairly well the law of Voigt and Thomson. The study of the magnetic properties of single iron crystals shows the existence of a molecular field, varying with the orientation of the axes in relation to the field. The variation of the electric resistance with the magnetic field and the magnetostriction of these crystals depend equally on the orientation of the crystal axes.

The Conditions for the Formation of Cementite. G. Charpy and P. Pingault. (Paper read before the Académie des Sciences, Oct. 1, 1928 : Génie Civil, 1928, Vol. 93, Oct. 13, pp. 361–362). The authors carried out tests on the carburisation of filings of electrolytic iron

carefully freed from hydrogen. The iron could be completely converted into cementite which was proved to be stable up to at least 1000° C. The progress of the carburisation was observed by density determinations and by measuring the magnetic properties.

X-Ray Study of the Structure of Quenched Steel. N. J. Seljakow, G. V. Kurdumoff, and N. T. Goodtzow. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Apr., pp. 222–230). Conclusion of a previous article (see Journ. I. and S.I., 1928, No. I. p. 923). The present instalment gives the results of the authors' investigations. A body-centred tetragonal structure approximating to α-iron was proved to exist in quenched carbon steel. The relationship between the parameters of the body-centred tetragonal lattice increases, under similar quenching conditions, with the increase in the carbon content, and, for a given carbon content, it increases with the quenching temperature. A face-centred cubic lattice (austenite) was proved to be present in a quenched carbon steel. The body-centred tetragonal structure in quenched carbon steel should be regarded as a sort of solid solution of carbon in α-iron. The mechanism of the quenching of carbon steel may be represented as a process tending towards the conservation of a condition of the structure intermediate between the γ and α structures.

Metallurgical Theories for the Practical Iron and Steel Man. C. H. Plant. (Iron and Steel Industry, 1928, Vol. 1, Aug., pp. 350–352). The conclusion of a series of articles (see Journ. I. and S.I., 1928, No. I. p. 861). In the present instalment the preparation of specimens for macro- and micro-examination is described.

The Transformation of Austenite in Liquid Air. (Metallurgist, 1928, Aug. 31, pp. 118–119). The question is discussed whether the transformation of austenite by cooling in liquid air actually occurs at the very low temperature, or whether the change only takes place as the specimen warms up again afterwards. The results given by K. Schröter (Zeitschrift für anorganische und allgemeine Chemie, 1928, Vol. 169, Jan., p. 157) and by G. Tammann and E. Scheil (ibid., 1926, Vol. 157, Jan., p. 1) are put forward to show that the change does actually occur at the low temperatures.

Principles for the Employment of Metallography in Foundries. W. Zimm. (Giesserei-Zeitung, 1928, Vol. 25, Apr. 15, pp. 245–249). The elements of metallography of interest to the foundryman are discussed.

A Study of the Structure of Martensite. A. Allison. (Heat Treating and Forging, 1928, Vol. 14, June, pp. 624–626). The angular condition of martensite in hardened steels, with examples, and the effect of the angularity of structure on serviceability are discussed.

The Ramsden Reflex Micrograph. (Engineering, 1928, Vol. 126, July 13, pp. 42–44, 46). The reflecting microscope illustrated and described in the article is capable of dealing with all classes of micrographic work such as are encountered in the laboratory, but its construction is more robust so that it can be placed in the hands of less skilled operators. The object is placed upside down at the top of the apparatus, and the image formed through the microscope tube beneath is reflected at an angle by a mirror in the base on to a focusing screen at the side, which is inclined after the manner of a reading-desk. Provision is made for taking photomicrographs, and an accessory permits details, such as the title, &c., to be simultaneously recorded on the photograph.

On the Constitution of the Iron-Tungsten and the Iron-Molybdenum Alloys. H. Arnfelt. (Iron and Steel Institute, Carnegie Scholarship Memoirs, 1928, Vol. 17, pp. 1–21). X-ray analyses of the iron-tungsten and iron-molybdenum systems were made. In the former at least two intermediate phases were proved to be present. One, having a hexagonal structure and parameters $a_1 = 4 \cdot 727$ Å. and $a_3 = 7 \cdot 704$ Å., corresponded to the formula Fe_2W, there being four such groups in the unit cell. Its decomposition temperature lay between $1000°$ and $1450°$ C. Another phase had a trigonal lattice with parameters $a_1 = 4 \cdot 731$ Å. and $a_3 = 25 \cdot 76$ Å.; there were probably 40 atoms per unit cell. Crystals were separated and were found to have a composition corresponding to Fe_3W_2. Both these phases were homogeneous within concentration ranges of some extent, which, however, could not be determined exactly. In the iron-molybdenum system an intermediate phase, analogous to the trigonal iron-tungsten phase, was found; its parameters were $a_1 = 4 \cdot 743$ Å. and $a_3 = 25 \cdot 63$ Å. Crystals were separated and found to correspond to the formula Fe_3Mo_2. In this system there seemed to be no phase analogous to the hexagonal phase in the iron-tungsten alloys, but at a higher molybdenum content a new phase appeared which solidified primarily; it apparently decomposed at lower temperatures, and its lattice is unknown. Possibly a third intermediate phase occurs in the alloys containing comparatively little molybdenum.

HEAT-RESISTANT AND ACID-RESISTANT ALLOYS.

Metals Used in the Coking Industry. H. K. Suttle. (Paper read before the Coke-Oven Managers' Association, May 2, 1928 : Colliery Guardian, 1928, Vol. 136, June 1, pp. 2142–2143 ; June 8, pp. 2248–2249). The author discusses briefly the various applications of ferrous and non-ferrous alloys in the construction of coke-oven plants, with special reference to their corrosion-resisting properties.

Rust, Acid, and Heat-Resisting Steels. W. H. Hatfield. (Paper read before the American Iron and Steel Institute, Oct. 26, 1928). The steels considered are the 12 to 14 per cent. chromium stainless steels as used for cutlery and allied purposes, the 12 to 14 per cent. chromium stainless steels as used for turbine blading and general engineering purposes, the 12 to 14 per cent. chromium so-called " stainless iron," and the austenitic nickel-chromium steels. The author surveys the mechanical and physical properties of these steels.

Some Tests on the Acid Resistance of Purest Chrome-Nickel-Iron Alloys. W. Guertler and W. Ackermann. (Zeitschrift für Metallkunde, 1928, Vol. 20, Aug., pp. 269–279). Ni–Fe, Cr–Fe, and Ni–Cr–Fe alloys of great purity were prepared in order to avoid any effects due to impurities, especially carbon ; the test-pieces were cylindrical in shape. 20 per cent. and 1 per cent. HNO_3, 1 per cent. H_2SO_4, HCl, HCl + H_2O_2, acetic acid, 5 per cent. KOH, KOH + H_2O_2, and artificial sea-water were used to test the corrosion resistance of the alloys. In oxidising reagents, or those in which solution could cause the formation of a film of oxide, the chromium was the constituent which could afford protection ; in non-oxidising solutions nickel was the protecting agent. The tests in the sea-water were inconclusive, and those in HCl alone showed that all the alloys were more or less attacked. In the ternary alloys, those in which more than three-quarters of the molecules were iron suffered greater attack than pure iron ; if the iron content were lowered, however, passivity set in and could only be removed by heating. In some cases the limits of composition at which the resistance to attack changed, very abruptly sometimes, were very well defined.

Properties and Uses of the Rustless Steels. A. C. Iebens. (Berg- und Hüttenmännisches Jahrbuch, 1928, Vol. 76, Oct. 1, pp. 81–84).

Chromium Steels : Their Electrochemical Behaviour and Susceptibility to Rust. O. Meyer and A. Roesch. (Archiv für das Eisenhüttenwesen, 1928, Vol. 2, Aug., pp. 119–125). Corrosion tests were made in various salt solutions and acid solutions on chromium steels containing 13 to 14 per cent. chromium, and with varying carbon percentages, and the dependence of the rust-resisting properties of these steels on the carbon content, the previous heat treatment, and character of the surface is discussed and shown graphically in diagrams. It was attempted to establish the relation between susceptibility to rust and single potential of chromium steels, in order, by means of time-potential curves, to be able to compare their capacities to resist attack. In general, the attack sets in at a definite order of potential, and the course of the time-potential curves gives qualitative values concerning their behaviour during long-time corrosion tests.

Heat-Resisting Steels. Sir Robert Hadfield, Bt., and R. J. Sarjant. (Fuel Economy Review, 1928, Vol. 7, pp. 72–80). A discussion of the properties of heat-resisting steels and the developments in their applications for engineering purposes.

CORROSION OF METALS.

(For Coating of Metals, see p. 377.)

Corrosion in the Tin Can. I.—The Electrochemical Relations of Iron and Tin. R. H. Lueck and H. T. Blair. (Paper read before the American Electrochemical Society, Sept. 1928). In acid solutions free from appreciable concentrations of oxidising substances the usual electrochemical relations of iron and tin are reversed, tin assuming an anodic relation to iron. The polarity reversal in the iron-tin cell is due to the large value for the hydrogen overvoltage of tin as compared with that of iron. No reversal occurs if the accumulation of hydrogen on the initially cathodic tin surface is prevented. A hypothesis is suggested to explain the perforating character of certain red fruits, as opposed to many uncoloured fruits of equal hydrogen ion concentration which do not perforate.

Reversed Potentials in the Corrosion of Tinplate. C. L. Mantell and W. G. King, jun. (Transactions of the American Electrochemical Society, 1927, Vol. 52, pp. 435–444). The corrosion of tinplate has been studied from the electrochemical viewpoint, with special reference to the corrosion of tinplate in containers used for food products. With strong electrolytes, the polarity of the potential in various solutions between iron and tin electrodes reverses itself. Curves showing this reversal are given and the protective effect against perforation of the tinplate is discussed.

Embrittlement of Boiler Plate. S. W. Parr and F. G. Straub. (Illinois University, Engineering Experiment Station, 1928, Bulletin No. 177). The first investigation of the embrittlement of boiler plate was undertaken in 1912, and the results were published in Bulletin No. 94. The studies were resumed in 1926, and further results were presented in Bulletin No. 155. The present Bulletin, while primarily intended as a record of data secured since that date, constitutes also a résumé of the entire three years' work on embrittlement. The general conclusions to be drawn from the results may be summarised as follows : Embrittlement is caused by the combined action of stress and chemical attack caused by the presence of sodium hydroxide in the boiler water. Certain methods of water treatment tend to convert some safe waters into the characteristic type which produces embrittlement. The presence of sodium sulphate in the feed-water tends to retard the

embrittling effect of feed-waters containing sodium carbonate, and if in proper proportions will stop it entirely. The presence of phosphates, tannates, chromates, acetates, &c., will also inhibit the embrittling action of caustic soda if these salts are present in the boiler water in proper amounts. Methods for the introduction of these inhibiting agents to feed-waters have been worked out and are in operation in large power plants. No steel suitable for boiler plate has been found which is resistant to the embrittling action, of caustic soda.

The Embrittlement of Boiler Plate. S. W. Parr and F. G. Straub. (Mechanical Engineering, 1928, Vol. 50, July, pp. 523–528).

Corrosion of Iron. H. Endo. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 1111–1134). The present paper gives the results of experiments on the action of water, light, temperature, oxygen, acids, and salt solutions on the corrosion of iron, as well as on the mechanism of the passage of iron into the passive state in solutions of $K_2Cr_2O_7$, K_2CrO_4, $KClO_3$, and $KMnO_4$. It forms the first report of the results of a long series of experiments, which are to be extended to various investigations of the corrosion of iron and other metals.

Bureau of Standards Soil-Corrosion Studies. I.—Soils, Materials, and Results of Early Observations. K. H. Logan, S. P. Ewing, and C. D. Yeomans. (United States Bureau of Standards, 1928, Technologic Papers No. 368). This report sets forth the plans and scope of the Bureau's investigation of the relation of soils to the corrosion of buried pipe. The investigation was begun in 1922, and the field work has been so planned that specimens will be removed at about two-year intervals for a period of ten years. Of the specimens buried, about one-seventh have been removed for examination. The results so far indicate that in certain regions soil corrosion is an active enemy of buried pipe lines, that the material best suited to resist the action of one soil is not necessarily the best for other soil conditions, and that the use of some protective coating is desirable under a number of soil conditions.

Practical Study of Corrosion. E. H. Schulz. (Stahl und Eisen, 1928, Vol. 48, Oct. 4, pp. 1393–1401). In view of the fact that corrosion and means for lessening it have now come to be regarded as one of the most important problems confronting the steel maker, and more particularly the steel user, the question arises what are the best methods of test to adopt in carrying out investigations on corrosion, and means for checking it. A large amount of purely scientific work has been performed which has led to valuable results, but what is needed is work of more immediate practical utility. Of all problems connected with the testing of steel, there is none which presents so complex a

character as corrosion. The author then proceeds to review work by recent investigators which bears on the practical side of the question. The first aim should be to study the causes of the corrosion, and the agencies by which it is brought about. Creutzfeld has proposed the classifying of corroding agents into four main divisions : Corrosion due to atmospheric effects ; corrosion by natural waters ; corrosion by strongly attacking liquids, such as acids, alkalis, &c. ; and corrosion by oxidation at high temperatures. All these are natural agencies which not only cannot be brought under control, but are variable in character. The composition of a steel is not the only important factor influencing its corrodibility ; the quality of the surface is also of very great influence. The tendency to surface corrosion may be greatly affected by segregations or by straining in rolling or cold-working, as is shown by the following test with samples cut from a plain steel bar 1 in. sq. On each specimen one rectangular surface was prepared of the same size in each case. One such surface represented the external surface of the bar, one a longitudinal section along the central axis, and the third the cross-section of the bar. The other surfaces of the prisms were coated with wax, and the prepared surface of each prism was exposed to the action of dilute sulphuric acid. The losses of weight in mg. were :

Specimen.				As Rolled.	Annealed.
Machined external surface .	.	.	.	98	73
Section along the axis	.	.	.	. 245	139
Cross-section .	.	.	.	. 450	177

The difference of loss in the annealed specimens is noteworthy. It is difficult to lay down standard conditions for corrosion tests, but the author recommends that the following data should be noted in making any test :

A. *The Material.*—(1) The chemical composition. In studying the effect of small proportions of copper, it is most important to note the exact analysis of the material. (2) Previous treatment of the steel, whether rolled or forged and subsequently heat-treated. (3) Position of the specimen in the piece from which it is taken. (4) Quality of the original piece as regards segregations and inclusions. (5) Nature of surface of the test-piece. If bright it should be stated whether the surface is machined, ground, or polished.

B. *The Corroding Medium.*—The nature of the liquid should be exactly specified, whether still or in motion, and whether renewed during the test, and if so when.

C. *Other Conditions.*—(1) Shape and dimensions of the specimens ; (2) quantity of corroding liquid and form of vessel ; (3) method of suspension or fixing of specimen, giving as many data as possible, particularly the depth of the upper edge below the surface of the liquid.

D. *Recording the Results.*—Exact details of method of recording results are necessary. If the corrosion is determined by measuring

loss of weight, it should be stated how the specimen was cleaned. The measurement should be given in grm. or mg. per sq. cm.

The simplest way of determining loss by corrosion is to note the loss of weight after removal of the corrosion products. But the greatest care is necessary to avoid attack of the metal either by mechanical or chemical means. It is also to be recommended that the corrosion products themselves be chemically examined. Nevertheless, any penetration of corrosion cannot be judged by weighing, and to meet this difficulty Czochralski and Schmidt have proposed that corrosion test specimens should be subjected to tensile tests, and the degree of corrosion be judged by the loss of mechanical strength. Some results of such comparative tests are given, and the loss in strength is very noticeable after exposure of a specimen to corrosive attack.

Field Corrosion Tests with Copper Steel. K. Daeves. (Stahl und Eisen, 1928, Vol. 48, Aug. 23, pp. 1170–1171). The author reports very briefly the results of corrosion tests with barbed wire and wire netting, both black and galvanised, and with and without an addition of copper. The wires were stretched on wooden poles in the open air. The main results are recorded as follows :

	Period of Exposure. Months.	Kind of Steel.	Copper. %	Loss in Weight. %
Black wire	$21\frac{1}{2}$	No copper added	0·03	23·0
		Copper added	0·23	16·0
Galvanised wire .	$21\frac{1}{2}$	No copper added	0·03	12·0
		Copper added	0·23	7·0
Galvanised wire netting	18	No copper added	0·03	28·1
		Copper added	0·15	19·3

The copper content not only retards rusting but helps to preserve the zinc coating on the galvanised wire for a considerably longer time than on the wires without copper. Further corrosion tests with material containing various percentages of copper and with different coatings are in progress.

Corrosion Apparatus for Corrosion Tests. J. Hausen. (Stahl und Eisen, 1928, Vol. 48, Aug. 23, pp. 1174–1175). At the Berlin Congress and Exhibition of Materials for Industrial Use and Construction there was shown an apparatus for carrying out accelerated corrosion tests, designed by Duffek. Since the date of the exhibition modifications and improvements have been introduced, and a full description of its operation with an illustration of the apparatus is given. It consists mainly of a glass beaker containing 400 c.c. of water in which is placed

a mercury U-tube, similar to a barometric tube. The mercury in the cup forms the electrode. The specimen of metal to be tested is polished and washed in a mixture of ether and alcohol, and then suspended vertically in the water, the lower end being adjusted at a fixed distance above the surface of the mercury. The whole is enclosed in an air-tight vessel, and oxygen is gently forced through a tube fixed in a stopper into the water. The air escapes through an outlet into the open, until the vessel is entirely filled with oxygen. An oxygen pressure of 60 mm. water-gauge is then maintained in the vessel for 24 hr., after which the specimen is withdrawn, cleaned, and weighed. The 24-hr. attack is about twenty times stronger in its effect than a 6-day atmospheric test. The advantage of the mercury electrode is that it is permanent, and forms a standard electrode.

The Application of Electric Resistance Measurements to Study of the Atmospheric Corrosion of Metals. J. C. Hudson. (Proceedings of the Physical Society of London, 1928, Vol. 40, Apr. 15, pp. 107–131).

Service is Best Test of Steel. H. M. Boylston. (Iron Age, 1928, Vol. 121, June 7, pp. 1665–1668). The author points out that accelerated corrosion tests are not conclusive and are frequently unreliable. Some of the variables which discredit these tests are enumerated.

Principles of Electrolytic Studies on Corrosion. W. Blum and H. S. Rawdon. (Transactions of the American Electrochemical Society, 1927, Vol. 52, pp. 403–433). The authors describe their apparatus and method for carrying out electrolytic corrosion tests of metals.

The Deterioration of Structures in Sea-Water. Eighth (Interim) Report. (Department of Scientific and Industrial Research, London, 1928, H.M. Stationery Office). Reports on the examination of iron and steel specimens exposed at Colombo, Plymouth, Halifax, Auckland, and Southampton are contained in this publication.

The Practical Problems of Corrosion. Part III.—The Formation of Rust and its Consequences. U. R. Evans. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Mar. 9, pp. 55–62T). Rust is not the direct corrosion product of iron, but is a precipitate formed usually at a sensible distance from the point of corrosion itself; the variations observed in the chemical and physical character of rust are easily explained on the principles established by recent work. The rust produced by hard waters contains calcium and magnesium compounds, and as these are deposited on the cathodic portions and obstruct the diffusion of oxygen to the metal, they reduce the rate of corrosion. The effect of magnesium sulphate on the corrosion of half-immersed specimens has been measured; at ordinary temperatures this salt was

found always to reduce corrosion ; abnormal cases of acceleration described by previous workers (using fully immersed specimens) were not observed.

The " apparent volume " of the rust sludge produced by numerous liquids has been measured ; it may be several hundred times that of the iron destroyed, thus explaining the rapid choking of pipes. The true volume of rust also exceeds that of the iron destroyed, and the expansion may cause disintegration where the rust is precipitated within the metal, or in crannies between plates. This is more likely to occur in atmospheric corrosion than in immersed corrosion, but if a sufficient margin of strength exists, the expansion will merely serve to plug the pore or crevice with rust and the action will cease. Clearly, however, a large margin of safety ought always to be allowed in calculating the necessary dimensions of structures if corrosive influences are present, since the natural mechanical forces may sometimes be aided by the expansional stresses involved in the conversion of dense iron into voluminous rust. Points of special danger are those affected by vibration or alternating stresses, especially if the force is, on the average, tensional, whilst, in applying protective paints, due attention must be devoted to corners and crevices where moisture may escape evaporation even in dry weather.

The Practical Problems of Corrosion. Part IV.—The Corrosion of Wrought Iron in Relation to that of Steel. U. R. Evans. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Mar. 9, pp. 62–69T). As regards the hydrogen-evolution type of corrosion, different strata of wrought iron behave differently, the most attackable portion being in the middle, and the least attackable on the outside ; when once the attack reaches the interior portions, wrought iron is very quickly attacked by dilute acids. As regards corrosion of the oxygen-absorption type, steel is attacked slightly more quickly than wrought iron, but the difference is slight, and would usually not justify the adoption of wrought iron under conditions where the corrosion is likely to be of a uniformly distributed character. For resisting atmospheric attack, wrought iron, if mechanically sound, may under some conditions be distinctly superior (*e.g.* where plugging can stifle the attack before damage has commenced), but under other conditions (*e.g.* in great excess of acid) it may be distinctly inferior. In general, it may be said that under favourable conditions there is no reason why steel should not have a life similar to that of wrought iron, but that the peculiar structure of wrought iron gives it, under certain circumstances, a definite advantage in deflecting an attack of an intense localised character.

The Practical Problems of Corrosion. Part V.—Corrosion and Protection at the Contacts of Dissimilar Metals. U. R. Evans. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Mar. 23, pp. 73–77T).

A series of potential measurements indicate that copper and nickel are usually cathodic towards steel, zinc and cadmium are usually anodic, whilst tin and lead (also, under some conditions, aluminium) are variable. Measurements of loss of weight show that the corrosion of steel half immersed in sodium chloride solution is greatly enhanced by contact with copper, the effect being increased further by doubling the breadth of the copper strips; contact with nickel produces a small amount of acceleration, and contact with lead still less; acceleration by copper was found to be less marked in a hard water than in the salt solution, whilst nickel and lead produced no acceleration in the hard water.

Contact with zinc affords complete protection of steel in most liquids, but the amount of zinc sacrificed, although very small in waters containing calcium salts, was extremely serious in solutions of sodium chloride or sulphate—the zinc consumption being actually higher than the steel consumption which takes place if the zinc is not present.

The Relative Corrosion of Electro- and Hot-Galvanised Steel. W. S. Patterson. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Nov. 2, pp. 313–316T). Experiments have been conducted on hot-galvanised and electro-galvanised mild steel to investigate the comparative resistance to corrosion of the two types of coatings. Outdoor tests indicate that the hot-galvanised material is the more resistant during this type of exposure. During immersion in dilute potassium chloride solution the hot-galvanised product is also more resistant than the electro-galvanised material. How far these results can be attributed to the physical difference between the two types of coatings or to the influence of the alloy layer formed during hot-galvanising has not been established. It would appear, however, that both these items function in the results obtained.

Exposure under conditions where the corrosion deposit accumulates on the surface shows that the two types of coating appear to corrode in a similar manner. This is the case during exposure in saturated atmospheres where erosion does not occur.

During sub-acid corrosion, unless the electro-deposit is comparatively heavy, it is much less resistant to attack than the hot-galvanised deposit. This is chiefly due to the porous character of the electro-galvanised material. It has been shown that by increasing the thickness of the deposit its porosity as indicated by the action of dilute sulphuric acid diminishes, and ultimately the coating offers a considerable resistance to attack. Zinc forms a good protection for iron only so long as an adequate initial deposit is present, and this statement applies equally to the hot-galvanised material.

Report of Committee A–5 on Corrosion of Iron and Steel. (American Society for Testing Materials, June 1928, Preprint No. 13). Atmospheric and total immersion tests are reported. New specifications

for zinc-coated (galvanised) steel wire strand and barb wire are presented.

Accelerated Laboratory Corrosion Test Methods for Zinc-Coated Steel. E. C. Groesbeck and W. A. Tucker. (Bureau of Standards Journal of Research, 1928, Vol. 1, Aug., pp. 255–295). The two accelerated testing methods studied were the simulated atmospheric corrosion, using a moist gaseous mixture of sulphur dioxide, carbon dioxide and air, and the spray, using normal solutions of sodium chloride and ammonium chloride separately. A consistent relationship between the " life " and weight of the coating was shown by the results. The time required for the breaking down of the coating was considerably less for the first method than for the second. The coating was corroded in the first method in a progressive manner over the entire surface similar to that reported for galvanised materials corroded in the atmosphere under service conditions, and in the second method in a local and capricious manner. The presence or absence of about $0\cdot2$ per cent. of copper in the steel base produced no apparent effect on the results. Tests were also made on specimens which had been annealed for the purpose of converting the zinc coating into an iron-zinc alloy.

Corrosion at Discontinuities in Metallic Protective Coatings. U. R. Evans. (Paper read before the Institute of Metals, Oct. 1928). A study has been made of the corrosion occurring at different kinds of discontinuities in coatings of non-ferrous metals on steel ; the work has included sprayed coatings of copper, nickel, and aluminium, and, in addition, coatings of zinc and zinc-iron alloy produced by hot-galvanising, electro-deposition, spraying, and sherardising. Various thicknesses of coating were employed, and the specimens were subjected to six different types of corrosion.

The cracks produced by bending are more dangerous than uniformly distributed pores. If the coating metal is cathodic to steel, the steel is corroded ; copper under some conditions causes marked acceleration of the corrosion of steel at exposed places, nickel being less dangerous. If the coating metal is anodic to steel, the coating suffers corrosion preferentially, the steel thereby receiving protection ; thus steel coated with zinc usually suffers no corrosion even at cracks until the zinc becomes exhausted. Steel thickly covered with zinc usually fares better than thinly covered steel, notwithstanding the greater tendency to cracking ; old galvanised sheet carried more zinc than the modern material and generally lasted longer. Coatings of aluminium or zinc-iron alloys are themselves less attacked than coatings of free zinc, but for that very reason they afford less sacrificial protection to the underlying steel in certain waters. Zinc itself is rather rapidly attacked when partially immersed in a chloride solution, but alternate salt-spraying and drying was found to build up a protective film—a

fact which explains certain observations made on the behaviour of galvanised iron in service.

On Corrosion Phenomena. On Protective Agents in the Corrosion of Iron under the Conditions of Boiler Operation. A. Thiel and H. Luckmann. (Korrosion und Metallschutz, 1928, Vol. 4, Aug., pp. 169–177). Experiments on the corrosion of iron in water and solutions of acids, alkalies, and salts of various concentrations under different conditions of atmosphere, temperature, &c., are described. The rôle of salts in the formation of protective coatings was investigated, and the part played by mill scale is discussed. It is shown that sodium sulphate is very injurious to boilers if the circumstances prevent the precipitation of salt; sulphate can only protect, therefore, when precipitation of salt (formation of boiler scale) can occur. This may happen where there are local concentrations of alkali and sulphate; in this case the destruction to be feared from the concentrated alkali may be prevented if the more difficultly soluble sulphate deposits as a protective coating.

Erosion by Water-Hammer. S. S. Cook. (Transactions of the Royal Society, 1928, Vol. 119A, pp. 481–488). With the higher surface speeds and higher vacua now generally adopted in steam turbines, the leading edges of the moving blades, especially towards the exhaust end of the turbine, are frequently found to be eroded. The investigation of the problem of propeller erosion led the author to consider the case when a spherical cavity, in an incompressible fluid, is suddenly permitted to collapse, and he discusses its application to the explanation of the erosion of turbine blades.

Simple Apparatus for the Determination of the Resistance of Alloys to Corrosion. H. Thyssen and J. Bourdouxhe. (Revue Universelle des Mines, 1928, Vol. 19, July 15, pp. 63–67). The authors point out that in practice it frequently happens that the corrosive agent is not in a state of rest on the object under attack, and that if tests are to give comparable results they must be arranged so that the corrosive agent is circulated. They describe and illustrate a system of vessels so arranged that the circulation of the corrosive liquid may be carried on as long as may be desired by means of an ejector pump (the ordinary laboratory " vacuum " pump).

Corrosion and Metal Protection in Boiler Operation. R. Stumper. (Korrosion und Metallschutz, 1928, Vol. 4, Oct., pp. 217–227).

The Phenomena of Corrosion of Iron and Steel. A. Herrero and M. de Zubiria. (Paper read before the Iron and Steel Institute, Sept. 1928 : this Journal, p. 109).

Attack and Protection of Metallic Surfaces. E. de Winiwarter. (Revue Universelle des Mines, 1928, Vol. 18, May 1, pp. 130–145). The rusting of iron and steel and their protection against corrosion are discussed.

LABORATORY EQUIPMENT.

Metals Studied for Fifteen Years. H. W. Gillett. (Iron Age, 1928, Vol. 122, Aug. 30, pp. 509–512). A review of the work accomplished by the Metallurgical Division of the United States Bureau of Standards since its organisation in 1913.

Acoustic Laboratory for Testing Music and Other Steel Wires. W. B. White. (Paper read before the American Iron and Steel Institute, Oct. 1928). The author describes the methods and equipment of the American Steel and Wire Co. for the acoustic testing of wire.

Research Laboratory—American Steel Foundries. W. C. Hamilton. (Paper read before the American Foundrymen's Association, May 1928). The equipment of the research laboratory of American Steel Foundries is described and illustrated. The work carried out is chiefly concerned with the investigation of steel for castings and its heat treatment.

CHEMICAL ANALYSIS.

ANALYSIS OF IRON AND STEEL.

Notes on the Routine Analysis of Cast Irons and Iron Foundry Materials. A. Smith. (Foundry Trade Journal, 1928, Vol. 39, Aug. 16, p. 117; Aug. 23, p. 137; Aug. 30, pp. 145, 152; Sept. 13, pp. 187–188; Sept. 20, p. 212; Oct. 18, p. 284).

The Use of Liquid Amalgams in Volumetric Analysis. Part X.—Some New Methods for the Determination of Vanadium, Chromium, and Some Nitro Bodies. K. Someya. (Science Reports of the Tôhoku Imperial University, Sendai, 1928, Vol. 17, pp. 131–139).

Describes Sampling Methods for Grey Cast Iron. R. H. Hobrock. (Foundry, 1928, Vol. 56, Oct. 1, pp. 797–798).

A Study of the Hydrogen-Antimony-Tin Method for the Determination of Oxygen in Cast Irons. B. Kjerrmann and L. Jordan. (Bureau of Standards Journal of Research, 1928, Vol. 1, Nov., pp. 701–720). A comparison of the vacuum-fusion and the hydrogen-antimony-tin reduction methods for the determination of oxygen in cast iron indicated that lump samples rather than milled samples should be used to avoid erroneous results for oxygen, due chiefly to the adsorption of air and moisture on milled samples and, in a lesser degree, to surface oxidation. The precision of the hydrogen-reduction method was indicated as 0·006 per cent. oxygen using a 5-grm. sample, and 0·005 per cent. using a 10-grm. sample. The precision of the vacuum-fusion method was indicated as 0·001 per cent. using a 30-grm. sample. The rather complicated nature of the " blank " for the hydrogen-reduction method is pointed out and discussed. For application to cast irons containing oxygen within the range of the samples used—namely, from 0·01 to 0·04 per cent.—the vacuum fusion method is to be preferred on the basis of its greater precision. The limitation of the hydrogen-reduction method to silicon-free samples, which has been shown to be necessary in the case of low-carbon iron alloys, does not appear to hold for high-carbon alloys.

Influence of Certain Elements in Iron on Oxygen Determination according to the Hydrogen Reduction Method. P. Bardenheuer and C. A. Müller. (Archiv für das Eisenhüttenwesen, 1928, Vol. 1, May, pp. 707–709; Stahl und Eisen, 1928, Vol. 48, June 14, p. 795).

According to P. Oberhoffer and his collaborators, the oxygen combined with iron and manganese can be determined by the hydrogen-reduction method only in such steels as are low in carbon and free from silicon. The authors have now made a series of determinations to discover the influence of nitrogen, phosphorus, and sulphur on the accuracy of the results in estimating oxygen by the hydrogen-reduction method. The experiments show that in ordinary commercial steels neither the nitrogen content nor the sulphur content appreciably affect the oxygen determinations, but the phosphorus, on the other hand, exercises a considerable influence on the results. The method is therefore only suitable for such steels as are low in carbon and have no silicon, aluminium, or other metals in their composition, and are, besides, practically phosphorus-free.

Nitrogen in Technical Iron. V. N. Svetchnikoff. (Revue de Métallurgie, Mémoires, 1928, Vol. 25, Apr., pp. 212–221 ; May, pp. 289–297). After a review of the work of other investigators, the author describes two examples, taken from practice, of the adverse effect of the presence of nitrogen in mild steel. He then describes the method of estimating nitrogen in steel (Kjeldahl) and discusses the question of the liquation or segregation of that element in steel. He next considers the absorption of nitrogen by iron and the rôle played by the impurities in that process. The influence of the duration of blowing in the Bessemer converter, of the composition of the pig iron, of the temperature, and of the blast pressure are dealt with. The author describes his own experiments carried out to elucidate the various points considered and records his results.

Nitrogen in Metals. B. Thomas. (Proceedings of the Staffordshire Iron and Steel Institute, 1927–28, Vol. 43, pp. 60–79). The work of previous investigators is reviewed and the ordinary methods of gas analysis are criticised. Discrepancies which occur in estimating nitrogen by difference are pointed out, and the author's investigation of the determination of nitrogen in combined form is described.

Modified Apparatus for Determination of Sulphur in Iron and Steel. M. H. Steinmetz. (Industrial and Engineering Chemistry, 1928, Vol. 20, Sept., pp. 983).

The Determination of Small Amounts of Carbonate in Presence of Excess of Sulphide and Chloride, with Particular Reference to the Analysis of Metallic Corrosion Products. W. H. J. Vernon and L. Whitby. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Sept. 7, pp. 255–259T).

The Determination of Vanadium in Steel. A. T. Etheridge. (Analyst, 1928, Vol. 53, Aug., pp. 423–428). The method consists in

removing the iron and other interfering metals, leaving a solution of the vanadium which can be determined by the ordinary permanganate titration. This is carried out in two main operations, namely, the iron is removed as chloride by the ether extraction process, and the rest of the interfering metals are removed by electrolysis over a mercury cathode. Full details are given in the paper together with instructions for dealing with special cases, such as high-silicon steels, tungsten steels, high-chromium steels, molybdenum steels, high-manganese steels, &c.

A New Precipitation Method for the Determination of Vanadium and its Application to Steel Analysis. B. S. Evans and S. G. Clarke. (Analyst, 1928, Vol. 53, Sept., pp. 475–485). The method depends on the following two points : (a) ferric iron in a boiling, faintly alkaline solution is quantitatively converted into ferrocyanide by the addition of sodium sulphite and potassium cyanide ; (b) in a fairly strongly acid solution vanadium ferrocyanide is completely precipitated. Nickel is the only interfering metal, though in the analysis of steels with low vanadium contents molybdenum if present requires special attention. The steel is dissolved in sulphuric acid in the usual way ; to the solution is added citric acid followed by hot concentrated sodium carbonate until just alkaline. Nickel is precipitated by dimethyl-glyoxime, and sodium sulphite and potassium cyanide are added to convert the iron to ferrocyanide. Acidifying the solution brings down the vanadium ferrocyanide, which is filtered off, ashed, and fused with fusion mixture containing some sodium phosphate. The melt is leached with hot water, and the filtered solution is finally prepared for titration with permanganate. For low-vanadium steels the process is the same except that tungstic oxide, insoluble in the first dissolving acid, is filtered off, and that the acidity of the solution from which the vanadium ferrocyanide is precipitated is increased ; finally the vanadium is estimated colorimetrically. The paper contains the results of trials made to check the accuracy of the method, and notes on the conversion of ferric salts into ferrocyanide, and on the conditions of acidity for precipitating vanadium ferrocyanide, are added. There is also a useful brief summary of the behaviour of the metals likely to be met with in the method.

Vanadium in Chrome-Vanadium-Tungsten Steels. H. H. Willard and P. Young. (Industrial and Engineering Chemistry, 1928, Vol. 20, July, pp. 764–768). Vanadium is determined without separation from tungsten, chromium, molybdenum, and iron by selective oxidation with bromate in a solution containing ammonium salts and a definite concentration of hydrochloric acid. The excess of bromate is removed by boiling, and the vanadic acid titrated electrometrically with ferrous sulphate.

Tungstic acid is kept in solution by dissolving it in sodium hydroxide

and pouring it back into the original solution to which sufficient ferric sulphate has been added. In this soluble form it does not interfere.

Diphenylbenzidine, like diphenylamine, is a very satisfactory internal indicator for the titration of vanadic acid with ferrous sulphate. Tungstic acid, even in small amounts, prevents the formation of the indicator colour, and therefore must be removed, but molybdenum does not interfere. The small amount of vanadium in the tungstic acid is estimated colorimetrically as yellow vanado-tungstic acid by dissolving the tungstic acid in alkali and acidifying this solution with phosphoric acid.

Persulphate Method for Chromium plus Vanadium in Chrome-Vanadium-Tungsten Steels. H. H. Willard and P. Young. (Industrial and Engineering Chemistry, 1928, Vol. 20, July, pp. 769–770).

The Estimation of Tungsten in Ferro-Tungsten and in Tungsten Steel. L. Moser and K. Schmidt. (Zeitschrift für angewandte Chemie, 1927, Vol. 40, June 8, pp. 667–668). A small quantity of finely powdered ferro-tungsten or a larger amount of moderate-sized pieces of tungsten steel is placed in a combustion boat and heated to a dull red heat while a mixture of air (free from CO_2 and moisture) and CCl_4 is passed over it. The tungsten and iron are volatilised as chlorides and are collected in a dilute nitric acid solution, where the iron remains in solution while the tungsten hydrolyses to WO_3. After evaporating to dryness the iron is removed from the WO_3 by washing and by heating with NH_4Cl and NH_4Br to 300° C.; SiO_2 is removed by HF. The WO_3 is weighed. The volatilisation of the iron may be prevented by adding KCl to the charge; a double chloride not volatile at a dull red heat is formed. The WCl_3 is hydrolysed in water, and by a special method the element is precipitated as benzidine tungstate.

Rapid Method for the Estimation of Nickel. S. G. Spacu and J. Dick. (Zeitschrift für analytische Chemie, 1927, Vol. 71, Nos. 11 and 12, pp. 442–446). The authors describe a method for determining nickel by precipitating it and weighing it as a compound of nickel sulphocyanide and pyridine ($NiPy_4(SCN)_2$), 1 grm. of which corresponds to 0·1195 grm. of nickel. The compound is precipitated as fine sky-blue prismatic crystals.

On the Rapid Estimation of the Silicon Contents of Iron-Silicon Alloys by the Determination of the Density. W. Denecke. (Giesserei Zeitung, 1928, Vol. 25, May 15, pp. 304–306). The author first explains the relationship between the density and silicon contents of Fe–Si alloys as indicated by the constitutional diagram, and then describes various methods of estimation with their results. He next reports his own results obtained by Schlumberger's method and makes suggestions for its improvement.

ANALYSIS OF ORES.

Remarks on the Estimation of Iron in the Ferrous State. E. Dittler, (Zeitschrift für anorganische und allgemeine Chemie, 1926, Vol. 158. Dec. 10, pp. 264–276). The estimation of FeO in ores, minerals, &c., containing small quantities of magnetic pyrites or large amounts of iron pyrites—sulphides decomposed by acids—is difficult because the H_2S liberated reduces the ferric iron already in solution and the iron in the sulphide passes into the ferrous condition. These difficulties are avoided by passing a rapid stream of CO_2 through the liquid, which sweeps out the H_2S before the reduction can occur. 4 to 5 grm. of ore or mineral is treated in a Corleis apparatus with 50 c.c. of H_2SO_4 (1 : 1) or HCl (sp. gr. 1·19) ; gentle heat is applied, and the H_2S is collected in two absorption flasks containing 100–150 c.c. of H_2O_2 (3 per cent.) plus 60 c.c. of ammonia. The H_2SO_4 formed is estimated and the corresponding amount of FeO is calculated. The concentration of the acid prevents the interaction of the FeS_2 with ferric iron salts to produce ferrous iron.

Analysis of Chrome Iron Ore. E. Dittler. (Zeitschrift für angewandte Chemie, 1928, Vol. 41, Feb. 4, pp. 132–133). According to the author, fusion of chrome iron ore with sodium carbonate is never complete, and a method by which analysis is best carried out is described.

ANALYSIS OF FUEL.

New Method of Determining the Volatile Matter Contents in Fuels for which, on Account of the Projection of Particles, the usual Method cannot be applied. L. F. Dooremans and D. J. W. Kreulen. (Chemisch Weekblad, 1927, Vol. 24, Nov. 12, pp. 562–563). In order to prevent the projection of sparks in the determination of the volatile matter in coals rich or poor in these constituents, the authors propose to cover the coal with a layer of sand. In the case of coals with high volatile contents a heavy deposit of soot is produced in the sand, but as the same thing happens in the ordinary method of determination no special correction is necessary. For the rest, the determination follows the conventional method.

Methods of Analysis of Coal. (Revue Universelle des Mines, 1928, Vol. 19, July 15, pp. 68–70). An abstract in French of Department of Scientific and Industrial Research, Fuel Research Board, Bulletin No. 7, 1927.

The Grinding of Coke for Analysis. J. Hiles and R. A. Mott. (Fuel in Science and Practice, 1928, Vol. 7, Nov., pp. 509–511). The work

of the United States Bureau of Mines resulted in the recommendation of porcelain ball-mills and carefully controlled roll-crushers for the pulverisation of large quantities of coke (200 grm. or more) so as to pass a 60-mesh sieve. For daily control testing at a coke-oven or blast-furnace plant, a much smaller quantity of coke is sufficient for the determination of ash, sulphur, phosphorus, &c. For these smaller quantities and for works in which a ball-mill or roll-crushers are not installed, a manganese-steel mortar is recommended. The use of Wedgwood-ware mortars should be viewed with suspicion, and iron mills and iron bucking boards should on no account be used.

Graphical Calculation of Gas Combustion Analyses. R. Jeller. (Berg- und Hüttenmännisches Jahrbuch, 1927, Vol. 75, Mar. 31, pp. 1–22).

An Apparatus for Continuous Gas Analysis. E. C. White. (Journal of the American Chemical Society, 1928, Vol. 50, Aug., pp. 2148–2154). An apparatus is described for the continuous automatic analysis of certain gases, utilising the change in electrical conductivity of a solution that has been exposed to the gas in a device for controlling the volume ratio. Two methods of calibrating the apparatus are given. Among the gases capable of estimation by this means NH_3, HCl, SO_2, Cl_2, H_2S, and CO_2 are mentioned. An actual adaptation for the determination of CO in the presence of H_2 is described in detail.

The Analysis of Gaseous Mixtures containing Carbon Dioxide, Carbon Monoxide, Hydrogen, and Methane. W. E. J. Broom. (Journal of the Society of Chemical Industry, 1928, Vol. 47, Sept. 21, pp. 276–278T).

Notes on the Sampling of Materials. W. R. D. Jones. (Metal Industry, 1928, Vol. 32, June 15, pp. 585–588, June 22, pp. 609–612 ; Vol. 33, July 6, pp. 3–4 ; July 13, pp. 27–28 ; Aug. 10, pp. 125–128 ; Aug. 31, pp. 199–203). The general principles involved in the sampling of materials, and their applications to the sampling of gases and liquids, coal, ores, and metals, are dealt with.

Sampling of Pulverised Fuel from Air Streams. L. T. Work. (Paper read before the American Society for Testing Materials, June 1928). The author discusses the principles of stream flow and the settling action of particles in moving streams of air. Several types of sampling equipment are described.

ANALYSIS OF REFRACTORY MATERIALS.

Determination of Iron Oxide and Titania in Clay Refractories. W. R. Kerr and E. B. Read. (Journal of the American Ceramic Society,

1928, Vol. 11, Nov., pp. 845–850). The direct bisulphate fusion method offers a rapid procedure for the determination of iron and titania, but is not suitable for all types of clays or for fired products. By treating with hydrofluoric and sulphuric acids, dissolving with dilute hydrochloric and precipitating the R_2O_3 by ammonium hydroxide, and then fusing with potassium bisulphate, the iron and titanium oxide can be titrated with accuracy.

Analysis of Bauxite and of Refractories of High Alumina Content. G. E. F. Lundell and J. I. Hoffmann. (Bureau of Standards Journal of Research, 1928, Vol. 1, July, pp. 91–104). The authors report the results of a study of analytical details involved in the analysis of bauxite and burnt refractories of high alumina content. Accurate analysis of these materials is a far more difficult problem than it is ordinarily thought to be. In spite of the fact that the determination of alumina is usually regarded as very simple, extreme values of $54 \cdot 84$ and $56 \cdot 88$ per cent. have been reported on the analysis of a sample of bauxite with $55 \cdot 06$ per cent. of alumina. The improper drying of bauxite and the difficulty of getting burnt refractories into complete solution were found to be sources of error. An umpire method is given for the determination of SiO_2, Al_2O_3, P_2O_5, Cr_2O_3, V_2O_5, Fe_2O_3, TiO_2, ZrO_2, CaO, and MgO. In addition, a routine method for Al_2O_3 is described. In this method a solution of the sample is divided into three aliquots. In the first aliquot the Al_2O_3, Fe_2O_3, TiO_2, ZrO_2, P_2O_5, and V_2O_5 are precipitated by NH_4OH. In the second aliquot the Fe_2O_3, TiO_2, ZrO_2, and V_2O_5 are precipitated by cupferron. In the third aliquot the P_2O_5 is determined and the Al_2O_3 is then found by difference.

The Use of 8-Hydroxyquinoline for the Chemical Analysis of Silicates. J. Robitschek. (Journal of the American Ceramic Society, 1928, Vol. 11, July, pp. 587–594). A method for the gravimetric and titrimetric determination of different metals, devised by Berg, is used for the analysis of silicates. Alumina and magnesia are precipitated with 8-hydroxyquinoline, and the precipitates can be either dried and weighed or dissolved and titrated.

The Determination of Iron in Silicates. A. E. J. Vickers. (Transactions of the Ceramic Society, 1927–28, Vol. 27, pp. 156–160). Methods are described for the determination of both ferrous and ferric oxides when present in silicates. Special directions are included for the use of the Reinhardt method of titrating iron.

NOTICES OF RECENT BOOKS PRESENTED TO THE LIBRARY.

" *Congrès International pour l'essai des Matériaux. Amsterdam, September 12–17, 1927.*" La 8vo. Vol. I. (Section A, " *Métaux* "), pp. xvii + 580. Illustrated. Vol. II. (Section B, " *Ciment, Pierres et Béton* ") (Section C, " *Divers* "), pp. ix + 737. Illustrated. The Hague, 1928: Martinus Nijhoff. (Price £2 10s.)

Before the war the International Association for Testing Materials held Congresses in various countries every three years. The headquarters of the Association were in Vienna, and the complete proceedings were published in three languages in the *Proceedings* of the Association. Due to force of circumstances, the work of this Association was of course suspended during the war, and when peace was restored there was little inclination on the part of the chief countries represented in the Association to renew the organisation on the old lines. Accordingly, the International Testing Association as it had existed from about 1896 was wound up, but the need for continued opportunity for the discussion of problems of international importance was strongly felt. Accordingly, a Committee was formed in Holland in 1925, which formulated proposals for the re-establishment of international collaboration in the work of studying methods of testing. A Permanent Committee was formed on which the principal industrial countries are represented by one member each, and arrangements were initiated for holding the first Congress of the new International Testing Association at Amsterdam in 1927.

The *Proceedings* of this Congress have now been published in two handsome volumes, which contain all the papers presented for discussion on that occasion. The material is divided into three sections : I. Metals ; II. Cement, Concrete, Stone, and Bricks ; III. Miscellaneous (Oils, Rubber, Preservatives against Corrosion, Wood, Coal, &c.). The work may be regarded as indispensable to all who find it necessary to keep abreast of the knowledge concerning the testing of materials from an international point of view. The Association is, in fact, an organisation for the purpose of securing and maintaining international contact on questions concerning testing and properties of materials, and it should be noted that questions of standardisation of materials and the drawing up of specifications are regarded as being outside the scope of the Association.

HANIEL, F. VON. " *Frachtverhältnisse und Frachtlage der Amerikanischen Eisenindustrie.*" 8vo, pp. 61. Illustrated. Berlin, 1928 : V.-D.-I. Verlag.

This work forms a short report on transport problems in the development of the iron and steel industry of the United States, showing how these have been solved. The question of the location of an iron industry at once raises the transport problem in its two main aspects—namely, the movement of the raw materials to the works where smelting and manufacture are carried on, and the movement of finished products from the works to the markets. The railway and waterway facilities that have been so fully developed in the United States to meet these needs are described, and tariffs and market conditions are recorded.

LUNGE and KEANE'S "*Technical Methods of Chemical Analysis.*" Second edition. Edited by Charles A. Keane and P. C. L. Thorne. Volume II. 8vo, pp. xix + 644. London, 1928: Gurney and Jackson. (Price £3 3s.)

The work is divided into the following sections: Iron and Steel; non-ferrous metals; metal salts; potassium salts; paints and pigments; paint vehicles; japans and varnishes. In the section on iron and steel, one chapter deals with the analysis of ores, fluxes, and slags, and another with the analysis of iron and steel products, and alloys of iron and steel with other metals. Under Non-Ferrous Metals, descriptions of analytical methods, both for the noble as well as for the base metals and their ores, are fully set forth. All the sections of this second volume of the work have been thoroughly revised and brought up to date, with the incorporation of the latest English and American methods, as has already been done in the case of Volume I.

MAWHINNEY, M. H. "*Practical Industrial Furnace Design.*" 8vo, pp. xi + 318. Illustrated. New York, 1928: John Wiley & Sons, Inc.; London: Chapman and Hall, Ltd. (Price 20s.)

The main part of this book was first published as a series of articles in *Forging—Stamping—Heat-Treating*, between December 1926 and February 1928. The author expounds practical methods for the solution of the problems and difficulties most frequently met with in the selection, design, and operation of industrial heating furnaces as distinguished from melting furnaces. It is widely recognised that the conservation of fuel is one of the factors of chief importance in modern civilisation, and there is no doubt that it is the industrial use of fuel that offers the widest field for introducing economies in its consumption. In the book it is attempted to make a clear presentation of the conditions which affect furnace operation, in order to bring about a better understanding of the way in which fuel can be conserved to a much greater extent than it is under the conditions still extensively prevailing in many industries. In comparison with the rapid advance made in the science of metallurgy, little real progress has been achieved in the theory of design and equipment of furnaces. The book will have fulfilled its principal object if it helps to arouse interest in the investigation and improvement of wasteful forms and design of industrial furnaces, and in the better utilisation of opportunities for selecting the right type of furnace and right kind of fuel to suit any specific case.

RÉGNAULD, M. "*Méthodes et Procédés Métallurgiques.*" 8vo, pp. 342. Illustrated. Paris, 1929: Gauthier-Villars et Cie. (Price 60 francs.)

The author suggests that in the study of metallurgical problems it is wiser to reject empiricism and to cultivate a mistrust of intuition. It is true that much of Bessemer's work was on empirical lines, and that he reached conclusions by intuition, but Bessemer is an isolated example of genius working by such methods, and he is therefore the exception which proves the rule. Neither is it possible for an individual to become a first-class metallurgist if he merely limits himself to the study in the laboratory of reactions of those substances which are to form the basis of operations on an industrial scale in the works. It is necessary to conduct trials on a large scale in order to obtain the practical knowledge necessary for the mental equipment of a modern metallurgist. The object of the book is to indicate the nature and practical application of materials used in steel

works for the construction of plant and apparatus, and that of the raw materials used in the processes themselves, such as ores, fluxes, ferro-alloys, and solid, liquid, and gaseous fuels. The processes themselves are next described, including the smelting, refining, and mechanical operations, and the heat treatment of the steel products. The book commends itself as a clear exposition of the ordinary modern metallurgical and mechanical processes involved in the production of iron and steel.

" *Tables Annuelles de Constantes et Données Numériques de Chimie, de Physique, de Biologie et de Technologie.*" Vol VI.: "*Années 1923–1924.*" 4to. Première Partie, pp. xxxiv + 679. Deuxième Partie, pp. xxix + 681–1675. Paris, 1928 : Gauthier-Villars et Cie ; New York : McGraw-Hill Book Co., Inc. (Price 610 francs.)

This work is published under the patronage of the International Union of Pure and Applied Chemistry by the International Committee nominated at the Seventh Congress of Applied Chemistry, held in London in June 1909, and is edited by Dr. Charles Marie, General Secretary of the Permanent Commission appointed by that International Committee. Vol. VI. is published in two parts, the work being continued on much the same lines as in the previous volumes. A new feature consists in the introduction of a chapter of numerical data relating to wireless telegraphy. The section dealing with geophysics is also considerably developed. A further new departure has also been made. The whole of the text of the section " Art de l'Ingénieur et Métallurgie," edited by L. Descroix, and forming part of this new volume, has been published in English as well as in French, a circumstance which will undoubtedly facilitate the circulation of this valuable work of reference in the English-speaking countries. This latter section, now printed in the two languages, includes the mechanical constants for a great variety of materials in common use for structural and other purposes, the thermal constants of refractory materials and fuels, and technical data concerning metals and alloys and their mechanical constants.

VERNON, W. H. J. "*A Bibliography of Metallic Corrosion.*" With an Introduction by H. C. H. Carpenter. 8vo, pp. xi + 341. London, 1928 : Edward Arnold & Co. (Price 21s.)

In the Introduction to this book, Professor H. C. H. Carpenter observes that the accumulated literature on the important subject of corrosion of metals and alloys is both extensive and complex. To summarise it in a formal treatise would need a work of inordinate length. The author has adopted a method which has enabled him to cover the whole field in a way which would not be possible in a work of a merely formal character, but which has enabled him to keep his book within very moderate limits of size. The book is entitled " A Bibliography of Metallic Corrosion," but it is far more than a bibliography, and its scope might be explained with more justice to the labours of the author if it were given the alternative title, " A Dictionary of Metallic Corrosion." The work is intended to supplement existing treatises on corrosion, and in the opinion of Professor Carpenter it is a most competent and successful effort in this direction. It will be most serviceable to all scientific investigators of the subject, and it should be of particular use to engineers who are grappling with everyday problems of corrosion, since it gives them ready access to the literature bearing on the difficulties with which they are confronted.

KIPPENBERGER, A. "*Die Kunst der Ofenplatten.*" Herausgegeben von Verein deutscher Eisenhüttenleute. 4to, pp. 52, with 70 plates and 46 figures in the text. Düsseldorf, 1928: Verlag Stahleisen m.b.H.

This work is dedicated " In gratitude to Dr. Ing. Emil Schrödter, the creator and untiring patron of the unique collection of stoveplates of the Verein deutscher Eisenhüttenleute." All those who have had the privilege of visiting the house of the Iron Metallurgists at Düsseldorf cannot fail to have been struck with admiration of this remarkable collection of cast-iron stoveplates, the credit for which entirely belongs to the well-known former Secretary of the Society, the late Dr. E. Schrödter. The work was begun many years ago, while the Society still occupied the premises in Jacobistrasse, and when it removed to the more extensive premises in the Breite Strasse in 1910, it was possible to make much better arrangements for the display of the collection.

As it at length became impossible to accommodate additional plates which were continually being received, the entire collection, now numbering over 1000 plates, was handed over in 1928 as a loan collection to the Municipal Art Museum of Düsseldorf.

Of all branches of art that of casting iron in relief is one that has been almost entirely neglected from the historical point of view. Many volumes have been written concerning porcelain, jewellery, tapestry, ivory, and wrought iron, but hardly anything concerning cast iron. The importance of stoveplates as works of art was realised many years ago by the V. d. E., when the work of collecting was begun, and although a few valuable specimens may be found in museums, these are generally stored away in a rusted and uncared-for condition.

The oldest plates in the exhibition of the V. d. E. are from the region of the Eifel, and they date from about the end of the fifteenth century. Evidence is conclusive that the art of casting these plates had its origin in the Eifel, and that it afterwards spread to the neighbouring lands of Luxemburg, Alsace, and the Siegerland. Dr. Schrödter brought specimens not only from these districts, but also from Belgium, Netherlands, England, and Scandinavia.

Besides their great interest from an artistic point of view, these plates form the earliest examples of the art of the ironfounder, and thus their historic value will be readily appreciated. Over 130 specimens of ornamental cast-iron plates are illustrated in the book. In particular, a valuable collection of plates is shown representing the ornamental work used in the construction of stoves of the Renaissance period. The reproductions are admirably made, and the whole work forms a valuable as well as a highly artistic contribution to the literature on the history of cast iron.

(456)

BIBLIOGRAPHY.

<small>Recent Publications relating to Ores, Fuels, and Metallurgy.</small>

American Society for Testing Materials. "*A.S.T.M. Tentative Standards, 1928.*" 8vo, pp. 932. Philadelphia : The Society. (Price $7.)

American Society for Testing Materials, 1928. "*Supplement to Book of A.S.T.M. Standards.*" 8vo, pp. 195. Philadelphia, 1928 : The Society.

Aragon, E. "*Résistance des matériaux appliquée aux constructions.*" Tome I. Deuxième édition, revue par P. Chambran. 8vo, pp. viii + 782. Paris, 1928 : Librairie Dunod. (Price 62 francs.)

"*Azetylen-Schweissung.*" Neueste Forschungsergebnisse. Dargelegt von Oberregierungsrat Dr. W. Rimarski. Hrsg. im Auftrage des Deutschen Acetylenvereins von Professor Dr. J. H. Vogel. 4to, pp. 96. Illustrated. Halle (Saale), 1928 : Carl Marhold.

Badenheuer, F. "*Der Einfluss der Kokille und der Desoxydation auf die Kristallisation ruhig erstarrender Blöcke.*" (Aachen, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 12. Illustrated. Düsseldorf, 1928 : Verlag Stahleisen m.b.H.

Baumont, M. "*La grosse industrie allemande et le charbon.*" 8vo, pp. 754. Paris, 1928 : Gaston Doin et Cie. (Price 45 francs.)

Baumont, M. "*La grosse industrie allemande et le lignite.*" 8vo, pp. 158. Paris, 1928 : Gaston Doin et Cie. (Price 18 francs.)

Becker, E., und O. Föppl. "*Dauerversuche zur Bestimmung der Festigkeitseigenschaften, Beziehungen zwischen Baustoffdämpfung und Verformungsgeschwindigkeit.*" (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. 304 H.) Pp. 28. Illustrated. Berlin, 1928 : V.-D.-I. Verlag. (Price 4.50 marks.)

Benedicks, C. "*Undersökningar över korrosion, uppträtande vid sulfatcellulosafabriker.*" Föredrag vid Svenska Pappers- & Cellulosaingeniörsföreningens möte den 26. februari 1927. 8vo, pp. 31, with 14 figures. Stockholm, 1927 : Ivar Haeggstroms Boktryckeri, A.B.

Beringer, B. "*Underground Practice in Mining.*" 8vo, pp. ix + 255. London, 1928 : Mining Publications, Ltd. (Price 20s.)

Berthelot, Ch. "*Les Combustibles dans l'Industrie moderne.*" 8vo, pp. 656. Illustrated. Paris, 1928 : Librairie J.-B. Baillière et Fils. (Price 102 francs.)

Birnbaum, H. "*Die Anlassvorgänge im gehärteten Stahl und ihre Beeinflüssung durch Silizium und Nickel.*" (Berlin, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 7. Düsseldorf, 1928 : Verlag Stahleisen m.b.H.

BRAGG, Sir W. H. "*An Introduction to Crystal Analysis.*" 8vo, pp. vii + 168 + 8 plates. London, 1928 : G. Bell & Sons, Ltd. (Price 12s.)

BRAGG, Sir W. H., and W. L. BRAGG. "*Die Reflexion von Röntgenstrahlen an Kristallen : Grundlegende Untersuchungen in den Jahren 1913 und 1914.*" 8vo, pp. xxvi + 148. Leipzig, 1928 : Leopold Voss. (Price 9 marks.)

BRANDT, G., and M. V. SCHWARZ. "*Die Praktische Nutzanwendung der Prüfung des Eisens durch Aetzverfahren und mit Hilfe des Microscopes.*" Pp. 200. Illustrated. Berlin : Julius Springer.

BREARLEY, A. W., and H. BREARLEY. "*Lingots et lingotières.*" Traduction française par C. F. Couleru. 8vo, pp. 224. Paris, 1928 : Ch. Béranger. (Price 50 francs.)

BRIGHAM, A. P. "*Geology.*" Revised and expanded by F. A. Burt. 8vo, pp. x + 554. New York and London, 1928 : D. Appleton & Co. (Price 12s. 6d.)

BRYSON, T. "*Mining Machinery : an Elementary Treatise on the Generation, Transmission, and Utilisation of Power, for Candidates for the Under-Manager's Certificate.*" (Pitman's Mining Certificate Series.) 8vo, pp. 394. London, 1928 : Sir Isaac Pitman & Sons, Ltd. (Price 12s. 6d.)

CHAPMAN, W. R., and R. A. MOTT. "*The Cleaning of Coal.*" 8vo, pp. xi + 680. London, 1928 : Chapman and Hall, Ltd. (Price 42s.)

CHOLODNY, N. "*Die Eisenbakterien.*" Beiträge zu einer Monographie. 8vo, pp. 162. Jena, 1928 : Gustav Fischer. (Price 12 marks.)

COCKERILL COMPANY. "*110 Anniversaire de la Fondation des Usines Cockerill, 1817–1927.*" Folio, pp. 165. Illustrated. Seraing, 1928.

"*Commission Interministérielle d'Utilisation du Combustible.*" 2e Congress (23 au 28 juin 1928) et 2e Exposition (23 juin au 8 juillet 1928) du chauffage industriel. 4to. Paris : Conservatoire nationale des Arts et Métiers.

"*Congrès International pour l'essai des Matériaux. Amsterdam, September 12–17, 1927.*" La. 8vo. Vol. I. (Section A, "*Métaux*"), pp. xvii + 580. Illustrated. Vol. II. (Section B, "*Ciment, Pierres et Béton*") (Section C, "*Divers*"), pp. ix + 737. Illustrated. The Hague, 1928 : Martinus Nijhoff. (Price £2 10s.) [See notice, p. 452.]

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : Engineering Research. Special Report, No. 8. "*Researches on Springs, 2 : The Measurement of the Displacements of Vehicle Springs under Road-Running Conditions ; with a Description of the Apparatus Employed.*" By J. H. Hyde. 8vo, pp. vi + 42. London, 1928 : H.M. Stationery Office. (Price 1s. 6d.)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : Engineering Research. Special Report, No. 9. "*Researches on Springs, 3 : Torsional Fatigue Tests on Spring Steels.*" By G. A. Hankins. 8vo, pp. iv + 24 + 2 plates. London, 1928 : H.M. Stationery Office. (Price 1s.)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : Engineering Research. Special Report, No. 10. "*Researches on Springs, 4. The Surging of Engine Valve Springs.*" 8vo, pp. iv + 28. Illustrated. London, 1928 : H.M. Stationery Office. (Price 1s.)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : Fuel Research. "*Physical and Chemical Survey of the National Coal Resources, No. 11. The Coalfields of Scotland : The Carbonisation of ' Kinneil Gas ' Coal.*" 8vo. pp. vi + 39. London, 1928 : H.M. Stationery Office. (Price 1s. 6d.)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : Fuel Research. Technical Paper, No. 20. "*The Thomas Recording Gas Calorimeter.*" 8vo, pp. vi + 42. London, 1928 : H.M. Stationery Office. (Price 9d.)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. "*Deterioration of Structures of Timber, Metal, and Concrete exposed to the Action of Sea-Water.*" Eighth (Interim) Report of the Committee of the Institution of Civil Engineers. Edited by J. Purser and H. J. Grose. 8vo, pp. iv + 75 + 9 plates. London, 1928 : H.M. Stationery Office. (Price 3s.)

DISNEY, A. N., Edited by, in collaboration with C. F. Hill and W. E. W. Baker. "*Origin and Development of the Microscope, as Illustrated by Catalogues of the Instruments and Accessories in the Collections of the Royal Microscopical Society, together with Bibliographies of Original Authorities.*" Preceded by an "*Historical Survey on the Early Progress of Optical Science,*" by the Editor. 8vo, pp. xi + 303 + 30 plates. London, 1928 : Royal Microscopical Society. (Price 17s. 6d.)

DORMANN, H. "*Ueber die feuerungstechnischen Grundlagen der Beheizung von Koksöfen.*" (Aachen, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 21. Illustrated. Munich, 1927 : R. Oldenbourg.

DOWNEY, J. F. "*The Timbering of Metalliferous Mines.*" 8vo, pp. 270. London, 1928 : Charles Griffin & Co., Ltd. (Price 25s.)

DRON, R. W. "*The Economics of Coal Mining.*" 8vo, pp. vii + 168. London, 1928 : Edward Arnold & Co. (Price 10s. 6d.)

ECKELL, J. "*Zur Frage nach den elektrochemischen Grundlagen der Metallkorrosion.*" 8vo, pp. 44. Marburg, 1927 : W. J. Beckers.

EMPIRE MINING AND METALLURGICAL CONGRESS (SECOND TRIENNIAL), CANADA, 1927. "*Proceedings.*" Edited by R. P. D. Graham. 8vo. Part I. : "*General,*" pp. xvii + 752. Illustrated. Part II. : "*Mining,*" pp. xvi + 749. Illustrated. Part III. : "*Petroleum,*" pp. xiv + 254. Illustrated. Part IV. : "*Metallurgy of Iron and Steel,*" pp. xiv + 588. Illustrated. Part V. : "*Non-Ferrous Metallurgy,*" pp. xiv + 104. Illustrated. Montreal, 1928. (Price, Complete Sets, $10 ; Single Parts, $3.)

EVANS, U. R. "*La corrosion des métaux.*" Traduit de l'anglais par A. Schubert. 8vo, pp. xvi + 324. Paris, 1928 : Librairie Dunod. (Price 54 francs.)

FOCKE, T. B. "*Étude de quelques Propriétés de très gros Cristaux de Fer.*" (Nancy, Universitaire, Dr.-Diss.) 8vo, pp. 155. Nancy, 1928 : Société d'Impressions Typographiques.

Frémont, Ch. "*Une des causes de rupture des ressorts d'horlogerie.*" (Études expérimentales de technologie industrielle, Mémoire 73.) 4to, pp. 12. Illustrated. Paris, 1928 : Ch. Frémont.

Frerich, R. "*Die Abhängigkeit des Frischvorganges in der Thomasbirne vom Temperaturverlauf.*" (Braunschweig, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 11. Düsseldorf, 1928 : Verlag Stahleisen m.b.H.

Gentry, F. M. "*The Technology of Low-Temperature Carbonisation.*" 8vo, pp. xvii + 399. London, 1928 : Baillière, Tindall and Cox. (Price 34s.)

Gluud, W. "*Handbuch der Kokerei.*" Band 2. 8vo, pp. viii + 301. Halle (Saale), 1928 : Wilhelm Knapp. (Price 32 marks.)

Gontermann, R. "*Entwicklung und Bedeutung der Siegerländer Spezialhochöfen.*" 8vo, pp. 72. Darmstadt, 1927 : Verlagshaus Darmstadt.

Granjon and Rosemberg. "*Traité de soudure autogène et d'oxy-coupage.*" Pp. 320, with 250 figures. Paris : Central de l'Acétylène et de la Soudure autogène. (Price 15 francs.)

Gruse, W. A. "*Petroleum and its Products.*" 8vo, pp. 377. New York, 1928 : McGraw-Hill Book Co. (Price $4.50.)

Guillet, L. "*Trempe, Recuit, Revenu.*" Traité théorique et pratique. Tome 2 : "*Pratique.*" 8vo, pp. vii + 296. Illustrated. Paris, 1928 : Librairie Dunod. (Price 75 francs.)

Haarmann, E. "*Der betriebswirtschaftliche Produktionsprozess einer Kokerei mit Einschluss der Gewinnung der Nebenprodukte.*" 8vo, pp. 61. Illustrated. Stuttgart, 1928 : C. E. Poeschel. (Price 5.50 marks.)

Haniel, F. von. "*Frachtverhältnisse und Frachtlage der Amerikanischen Eisenindustrie.*" 8vo, pp. 61. Illustrated. Berlin, 1928. V.-D.-I. Verlag. [See notice, p. 452.]

Hart, I. B. "*The Great Engineers.*" (The Great Scientists Series.) 8vo, pp. viii + 136. London, 1928 : Methuen & Co., Ltd. (Price 3s. 6d.)

Heil, W. "*Messung und Errechnung der Druckverluste, insbesondere in Siemens-Martin-Oefen.*" (Breslau, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 12. Düsseldorf, 1928 : Verlag Stahleisen m.b.H.

Houstoun, R. A. "*Intermediate Electricity and Magnetism.*" 8vo, pp. 170. Illustrated. London, 1928 : Longmans, Green & Co. Ltd.

Husband, J., and W. Harby. "*Structural Engineering.*" Fourth edition, revised and enlarged. 8vo, pp. xii + 458. London, 1928 : Longmans, Green & Co. Ltd. (Price 16s.)

"'*Hütte.*' Des Ingenieurs Taschenbuch." Hrsg. vom Akademischen Verein Hütte, e.V., in Berlin. 25., neubearb. Auflage Gesamtsachverzeichnis der Bände 1–4. 8vo, pp. 158. Berlin, 1928 : Wilhelm Ernst & Sohn. (Price 6 marks.)

"'*Hütte.*' Manuel de l'ingénieur." Traduit sur la vingt-quatrième édition allemande. 3 vols. Vol. 1, pp. 413. Vol. 2, pp. 1422. Vol. 3, pp. 1439. Paris, 1928 : Ch. Béranger. (Price 392 francs.)

JACOBS, F. R. "*The Abrasives Handbook.*" 8vo, pp. 547. Illustrated. Cleveland, Ohio, 1928 : Penton Publishing Co. (Price $5.)

JAEGER, W. "*Elektrische Messtechnik : Theorie und Praxis der elektrischen und magnetischen Messungen.*" Dritte umgearbeitete Auflage. 8vo, pp. xxiv + 553. Leipzig, 1928 : Johann Ambrosius Barth. (Price 40 marks.)

JOFFÉ, A. F. "*The Physics of Crystals.*" Edited by L. B. Loeb. 8vo, pp. xi + 198. New York, 1928 : McGraw-Hill Book Co., Inc. ; London : McGraw-Hill Publishing Co., Ltd. (Price 15s.)

KAUSCH, O. "*Die aktive Kohle : ihre Herstellung und Verwendung.*" (Monographien über chemisch-technische Fabrikationsmethoden, Band 42.) 8vo, pp. vii + 342. Halle (Saale), 1928 : Wilhelm Knapp. (Price 21.50 marks.)

KEREKGYARTO, G. "*Das Verdrehen der Metallstaebe.*" 4to, pp. 27. Illustrated. Budapest : Technologiai és Anyagvizsgalo Intézet.

KERPELY, K. VON. "*Die metallurgischen und metallographischen Grundlagen des Gusseisens.*" (Die Betriebspraxis der Eisen-, Stahl- und Metallgiesserei. Heft 7.) 8vo, pp. 120. Halle (Saale), 1928 : Wilhelm Knapp.

KERSHAW, J. B. C. "*The Recovery and Use of Industrial and other Wastes.*" 4to, pp. xvii + 212. London, 1928 : Ernest Benn, Ltd. (Price 25s.)

KNIBBS, N. V. S. "*The Industrial Uses of Bauxite : with an Account of its Origin, Occurrence, Composition and Properties.*" 8vo, pp. 141. London, 1928 : Ernest Benn, Ltd. (Price 21s.)

KRAUSE, H. "*Galvanotechnik (Galvanostegie und Galvanoplastik).*" 5. erg. Auflage. 8vo, pp. viii + 237. Leipzig, 1928 : Dr. Max Jänecke. (Price 5.40 marks.)

KREKELER, K. "*Die Prüfung der Bearbeitbarkeit der legierten Stähle für den Kraftfahrzeugbau durch spanabhebende Werkzeuge.*" (Aachen, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 20. Illustrated. Düsseldorf, 1928 : Verlag Stahleisen, m.b.H.

LASSIEUR. "*Electro-analyse rapide.*" Preface de A. King. Pp. 206. Illustrated. Paris : Les Presses Universitaires de France. (Price 20 francs.)

LATTRE, G. DE. "*Protection des Métaux contre la Corrosion.*" 8vo, pp. 204. Paris, 1927 : Édition de *L'Usine.* (Price 34 francs.)

LATTRE, G. DE. "*Technique de l'etirage.*" 8vo, pp. 247. Illustrated. Paris, 1928 : Édition de *L'Usine.*

LEFÈVRE, A. "*Pour les praticiens de la fonderie.*" Modeleurs, mouleurs, fondeurs. Tours de main et "trucs" d'atelier pour le travail par fusion de la fonte, du bronze, du laiton, de l'aluminium, des métaux usuels et des métaux précieux. 8vo, pp. viii + 224. Illustrated. Paris, 1928 : Librairie Dunod.

"*Le nickel et ses alliages.*" (Documentation technique. Applications industrielles.) "*Situation de la métallurgie du nickel,*" par L. Guillet, pp. 8 ; "*Métallurgie du nickel au Canada et aux États-Unis,*" par J. Galibourg,

pp. 20 ; " *Le nickel en Nouvelle-Calédonie*," par R. Contal, pp. 10 ; " *Le nickel pur et ses applications*," par G. Chaudron, pp. 8 ; " *Le nickelage*," par J. Galibourg, pp. 12 ; " *Les alliages de nickel et la corrosion*," par A. Portevin, pp. 20 ; " *Le nickel dans l'armement*," par G. Charpy, pp. 8 ; " *Le nickel dans les industries de l'automobile et de l'aviation*," par L. Guillet, pp. 10 ; " *Les alliages de nickel non sidérurgiques*," par Jean Cournot, pp. 26 ; " *Les aciers à haute teneur en nickel* " (Les anomalies des aciers au nickel et leurs applications), par C. E. Guillaume, pp. 11 ; " *Où en est l'industrie française dans les emplois du nickel*," par J. Dhavernas, pp. 8. Paris : Centre d'information du nickel.

LEVASSEUR, A. " *L'électrochimie et l'électrométallurgie*." Troisième édition. La. 8vo, pp. viii + 362, with 128 figures. Paris : Librairie Dunod. (Price 68.90 francs.)

LIDDLE, R. A. " *The Geology of Venezuela and Trinidad*." 8vo, pp. xxxix + 552 + 85 plates. Fort Worth, Texas, 1928 : J. P. MacGowan ; London : Thomas Murby & Co. (Price 33s. 6d.)

LIDGETT, A. " *Petroleum*." Third edition, revised and enlarged. 8vo, pp. 172. London, 1928 : Sir Isaac Pitman & Sons, Ltd. (Price 5s.)

LILLEY, E. R. " *The Geology of Petroleum and Natural Gas*." 8vo, pp. x + 524. London, 1928 : Chapman and Hall, Ltd. (Price 30s.)

LINDGREN, W. " *Mineral Deposits*." Third edition. 8vo, pp. 1049. Illustrated. New York, 1928 : McGraw-Hill Book Co., Inc. (Price $7.)

LUNGE AND KEANE'S " *Technical Methods of Chemical Analysis*." Second edition. Edited by Charles A. Keane and P. C. L. Thorne. Volume II. 8vo, pp. xix + 644. London, 1928 : Gurney and Jackson. (Price £3 3s.) [See notice, p. 453.]

MARTIN, G. " *A Treatise on Chemical Engineering applied to the Flow of Industrial Gases, Steam, Water, and Liquid Chemicals, including the Pneumatic Transport of Powders and Granulated Materials ; with Details for Calculating Fan Power, Pumping Power, Friction Losses in Pipes and the like, together with Full Practical Details of Measuring Flow and Viscosity of Gases and Liquids*." A Practical Treatise for Engineers, Works Chemists, Chemical Engineers, Furnace Operators, Plant Designers, Works Contractors, and Others. 8vo, pp. xxiii + 429 + 19. London, 1928 : Crosby Lockwood & Son. (Price 63s.)

MATTHAES, K. " *Die Kerbschlagprobe und die dabei auftretenden Erscheinungen*." (Dresden, Techn. Hochschule, Dr.-Ing.-Diss.) 8vo, pp. 99. Illustrated.

MAWHINNEY, M. H. " *Practical Industrial Furnace Design*." 8vo, pp. xi + 318. Illustrated. New York, 1928 : John Wiley & Sons, Inc. ; London : Chapman and Hall, Ltd. (Price 20s.) [See notice, p. 453.]

MERNAGH, L. R. " *Enamels : their Manufacture and Application to Iron and Steel Ware*." Pp. xiii + 228. London, 1928 : Charles Griffin & Co., Ltd. (Price 18s.)

MERRIMAN, M. "*Strength of Materials : A Text-Book for Secondary Technical Schools.*" Seventh edition, revised by T. Merriman. 8vo. New York, 1928 : John Wiley & Sons, Inc. ; London : Chapman and Hall, Ltd. (Price 8s. 6d.)

"*Mineral Industry : Its Statistics, Technology, and Trade During 1927.*" Edited by G. A. Roush. Vol. XXXVI. 8vo, pp. xvii + 766. New York and London, 1928 : McGraw-Hill Book Co., Inc. (Price £3.)

MOND NICKEL CO. "*Nickel and Its Alloys.*" 8vo. (A Loose-Leaf Binder containing Technical Publications issued from time to time by the Research and Development Department of the Mond Nickel Co., Ltd.)

MONYPENNY, J. H. G. "*Rostfreie Stähle.*" Übersetzt von R. Schäfer. Pp. 342. Illustrated. Berlin, 1928 : Julius Springer. (Price 27 marks.)

MORGAN, J. J. "*Manufactured Gas, a Text-Book of American Practice.*" 8vo, pp. 447. Illustrated. New York, 1928 : J. J. Morgan.

MORLEY, A. "*Strength of Materials.*" Seventh edition. London : Longmans, Green & Co. Ltd. (Price 12s. 6d.)

MORSE, J. K. "*Bibliography of Crystal Structure.*" 8vo, pp. xix + 164. Chicago, Ill., 1928 : University of Chicago Press ; London : Cambridge University Press. (Price 15s.)

NATIONAL PHYSICAL LABORATORY. "*Collected Researches.*" Vol. 20, 1927. 4to, pp. v + 444 + 13 plates. London, 1928 : H.M. Stationery Office. (Price 18s. 6d.)

NEILSON, J. B. "*Life of James Beaumont Neilson, F.R.S., Inventor of the Hot Blast.*" Compiled by T. B. Mackenzie. 4to, pp. 34. Illustrated. Glasgow, 1928 : West of Scotland Iron and Steel Institute.

NEUBURGER, M. C. "*Röntgenographie des Eisens und seiner Legierungen mit besonderer Berücksichtigung der Ergebnisse anderer Untersuchungsmethoden.*" (Sonderausgabe der Sammlung chemischer und chemisch-technischer Vorträge. Hrsg. von Professor Dr. W. Herz. Bd. 30. (H. 7–9.)) 8vo, pp. 124. Illustrated. Stuttgart, 1928 : Ferdinand Enke. (Price 11.25 marks.)

NEUENDORFF, G. "*Ueber die Schmelzflusselektrolyse von Eisen, Chrom und Mangan.*" (Breslau, Techn. Hochschule, Dr.-Ing.-Diss.) 8vo, pp. 61.

PFANHAUSER, W. "*Die elektrolytischen Metallniederschläge.*" Lehrbuch der Galvanotechnik mit Berücksichtigung der Behandlung der Metalle vor und nach dem Elektroplattieren. 7. Auflage. 8vo, pp. xiv + 912. Illustrated. Berlin, 1928 : Julius Springer. (Price 40 marks.)

PIPPARD, A. J. S. "*Strain Energy Methods of Stress Analysis.*" 8vo, pp. x + 146. London, 1928 : Longmans, Green & Co. Ltd. (Price 14s.)

QUAST, W. "*Die Entwicklung der Eisen Industrie im Sauerland.*" 8vo, pp. 40. Illustrated. Köln-Kalk, 1928 : Max Welzel.

RAGG, M. "*Vom Rost und vom Eisenschutz. Altes und Neues.*" 8vo, pp. 119. Illustrated. Berlin, 1928 : Union Deutsche Verlagsgesellschaft. (Price 8.30 marks.)

RALSTON, O. C. "*Zinkelektrolyse und nassmetallurgische zinkverfahren.*" Ins Deutsche übertragen von Georg Eger. Mit einem Nachtrag des Übersetzers. (Monographien über angewandte Elektrochemie, Band 47.) 8vo, pp. 282. Halle (Saale), 1928 : Wilhelm Knapp. (Price 21 marks.)

RÉGNAULD, M. "*Méthodes et Procédés Métallurgiques.*" 8vo, pp. 342. Illustrated. Paris, 1929 : Gauthier-Villars et Cie. (Price 60 francs.) [See notice, p. 453.

REYNOLDS, W. C. "*Atomic Structure as Modified by Oxidation and Reduction.*" 8vo, pp. viii + 128. London, 1928 : Longmans, Green & Co. Ltd. (Price 7s. 6d.)

RIEBENSAHM, P., and L. TRAEGER. "*Werkstoffprüfung (Metalle).*" (Werkstattbücher für Betriebsbeamte, Vor- und Facharbeiter. Hrsg. von Eugen Simon. H. 34.) 8vo, pp. 68. Berlin, 1928 : Julius Springer (Price 1.80 mark.)

ROMEIS, B. "*Taschenbuch der mikroskopischen Technik.*" 12. neubearbeitete und erweiterte Auflage des "*Taschenbuches der mikroskopischen Technik,*" von A. A. Böhm und A. Oppel. 8vo, pp. 732. Illustrated. Munich, 1928 : R. Oldenbourg. (Price 25 marks.)

SAKHAROV, P. V. "*Étude sur la question du recuit des tôles de chaudière après laminage.*" Pp. 94. Moscow : Commissariat du Peuple des Voies de Communication. [In Russian.]

SANCHO, A. P. "*Hierros, Aceros y Fundiciones.*" 8vo, pp. 344, with two volumes of plates. Madrid : Imprenta del Memorial de Artilleria. (Price 40 pesetas.)

SCHIMPKE, P., and H. A. HORN. "*Praktisches Handbuch der Gesamten Schweisstechnik.*" Band I. 2. Auflage. 8vo, pp. 222. Berlin, 1928 : Julius Springer.

SCHLIPPE, O. "*Untersuchung des Pressfinish-Verfahrens.*" (Dresden, Techn. Hochschule, Dr.-Ing.-Diss.) 4to, pp. 31. Illustrated. Berlin : Willfried Deyhle.

SCHUCHARDT, G. "*Kohlenelektroden für elektrische Oefen.*" Ihre Herstellung, Prüfung und Verwendung, nebst einer Uebersicht der deutschen Patente. 8vo, pp. 33. Berlin, 1928 : Polytechnische Buchhandlung A. Seydel.

SCRIVENOR, J. B. "*The Geology of Malayan Ore Deposits.*" 8vo, pp. 216. London, 1928 : Macmillan & Co., Ltd. (Price 16s.)

SEIBT, A. "*Adressbuch der deutschen Industrie.*" Offizieller Bezugsquellennachweis des Reichsverbandes der deutschen Industrie. 3. Auflage. Munich, 1928 : Max Heitner. (Price 18 marks.)

SEMENOFF, N., and A. WALTHER. "*Die physikalischen Grundlagen der elektrischen Festigkeitslehre.*" Pp. 168. Illustrated. Berlin, 1928 : Julius Springer. (Price 16.50 marks.)

SMITH, P. J. L. "*Higher Test Papers in Magnetism and Electricity.*" (Higher Test Papers Series.) 8vo, pp. iii + 100. London, 1928 : Sir Isaac Pitman & Sons, Ltd. (Price 3s.)

SPIEGEL, G. "*Stahl und Eisen-beton im Geschossgrossbau.*" Ein wirtschaftlicher Vergleich. 8vo, pp. 37. Illustrated. Berlin, 1928 : Julius Springer. (Price 1.80 mark.)

SWAIN, G. F. "*Festigkeitslehre.*" Übers. von A. Mehmel. Pp. 630. Illustrated. Berlin, 1928 : Julius Springer. (Price 34 marks.)

"*Tables Annuelles de Constantes et Données Numériques de Chimie, de Physique, de Biologie et de Technologie.*" Vol. VI. : "*Années 1923–1924.*" 4to. Première Partie, pp. xxxiv + 679. Deuxième Partie, pp. xxix + 681–1675. Paris, 1928 : Gauthier-Villars et Cie ; New York : McGraw-Hill Book Co., Inc. (Price 60 francs.) [See notice, p. 454.]

TIMOSHENKO, S., and M. LESSELLS. "*Festigkeitslehre.*" Traduction allemande par I. Malkin. Pp. 484, with 391 figures. Berlin : Julius Springer. (Price 28 marks.)

TRINKS, W. "*Industrieöfen.*" Band I. : "*Grundlegende Theorien und Bauelemente.*" 8vo, pp. xi + 248. Illustrated. Berlin, 1928 : V.-D.-I. Verlag. (Price 16 marks.)

UNCKEL, H. "*Ueber die Fliessbewegung im plastischen Material.*" 8vo, pp. 66. Illustrated. Berlin : Julius Springer. (Price 8 marks.)

VERNON, W. H. J. "*A Bibliography of Metallic Corrosion.*" With an Introduction by H. C. H. Carpenter. 8vo, pp. xi + 341. London, 1928 : Edward Arnold & Co. (Price 21s.) [See notice, p. 454.]

WENDT, R. E. "*Foundry Work.*" Second edition. 8vo, pp. 236. Illustrated. New York, 1928 : McGraw-Hill Book Co., Inc. (Price $2.)

WILD, R. "*Studies in Magnets and Magnetism.*" 8vo, pp. 70. London, 1928 : A. H. Stockwell, Ltd. (Price 2s. 6d.)

WILLET, E. F. "*Coal, Iron, and Steel in Europe.*" 4to, pp. 65. New York, 1928 : Dillon, Read & Co.

WINCHELL, A. N. "*Elements of Optical Mineralogy : an Introduction to Microscopic Petrography.*" Third edition, revised and enlarged. Part I. : "*Principles and Methods.*" 8vo, pp. viii + 238. New York, 1928 : John Wiley & Sons, Inc. ; London : Chapman and Hall, Ltd. (Price 17s. 6d.)

SUBJECT INDEX.

[References to the papers read before the Institute are indicated by the word
Paper following the page number. The letter *P.* denotes a reference to a
subject incidentally mentioned in a paper. The letters *D.* and *A.* denote
references to discussions on papers and to the section dealing with abstracts
respectively.]

A.

2 H

C.

D.

E.

F.

M.

N.

S.

T.

U.

X.

Y.

Z.

NAME INDEX.

A.

ABRAMS, H., on thermoelectric measurement of temperatures, 355A.
ACKERMANN, W., on acid resistance of chrome-nickel iron alloys, 434.
ADAM, A. T., on ageing of cold-drawn steel, 189D.
———— on Tru-lay wire ropes, 376A.
ADAMSON, E., on tests of cast iron, 92D.
———— remarks on Pfeil's paper, 185D.
ADEY, S. W., on flow of oil in pipes, 295A.
AGDE, G., on reactions in coking of coal, 274A.
AICHHOLZER, W., on flakes in chromium steel, 418A.
ALLIN, G. E., on pulverised coal, 267A.
ALLISON, A., on grain-growth in steel sheets, 164D.
———— on structure of martensite, 432A.
AMEEN, E., on gases occluded in steel, 340A.
AMELSITZ, on displacement of cast iron by steel, 387A.
ANACKER, M. von, on centrifugal casting, 320A.
ANDERSON, O. W., on heat treatment furnace, 357A.
ANTZ, E. L., on iron industry of the Saar, 305A.
APPLEYARD, K., on dry cleaning of coal, 262A.
ARBOLEDAS, J. S., elected member, 9.
ARMSTRONG, H. C., on fuel control, 251A., 256A.
ARNFELT, H., on iron-tungsten and iron-molybdenum alloys, 433A.
ARNOLD, E., on Collin coke cooling system, 276A.
ASKEW, H. O., on Bergius process for liquefaction of coal, 293A.
AUBEL, R. van, on X-ray examination of minerals, 241A.
AUDIBERT, E., on action of catalysts on carbon monoxide and hydrogen, 294A.
AULICH, P., on testing of moulding sands, 317A.
AVANZINI, H. von, on strip mills, 348A.
AYLING, J. S., on carburising compounds, 363A.

B.

BABLIK, H., on pickling, 376A.
BADENHEUER, F., on solidification of ingots, 340A.
BAILEY, F. J., on blast-furnace working, 299A.
———— on waste heat recovery, 256A.
———— elected member, 9.
BAILEY, I. A., on gas-producers, 283A.
BAIN, E. C., on constituents of stainless steel, 429A.
BAKER, E. M., on chromium plating, 378A.
BAKER, H. A., on coal in Newfoundland, 237A.
BALLAY, on martensitic quenching of nickel-chrome cast iron, 385A

D.

G.

H.

I.

J

K.

M.

N.

O.

OBINATA, I., on self-hardening property of chromium steel, 408*A*.

O'BREEN, J. E., on combustion control, 252*A*.

OERTEL, W., on annealing of transformer sheets, 370*A*.

OESTERREICHER, K., on foundry practice, 310*A*.

OETKEN, F. A., on Lurgi process, 280*A*.

OKANIEWSKI, W., on mining in Jugoslavia, 238*A*.

O'NEILL, H., on hardness in relation to cold-working and machining properties of metals, 406*A*.

ORLAND, J.—

      Paper on " The Influence of Pearlitisation below the Ar₁ Point on the Mechanical Properties of Carbon Steels, 131.—*Discussion*, 139.—*Author's Reply*, 140.

ORROK, G. A., on high-pressure steam boilers, 252*A*.

OSANN, B., on blast-furnace gas, 300*A*.

—— on blast-furnace reactions, 299*A*.

—— on high-duty cast iron, 311*A*.

—— on steel foundry practice, 322*A*.

OSTERMAN, P. C., on heat-treatment furnaces, 357*A*.

OTHMER, D. F., on measurement of surface temperature, 355*A*.

OTIS, A. N., on temperature control for heating apparatus, 256*A*.

OTTO, C., elected member, 11.

OTTO, C. A., on cupola practice, 307*A*.

P.

PAGE, A. R., on macrographic examination of forgings, 428*A*.

PAHL, H., on ignition of liquid fuels, 292*A*.

PALMER, F. R., on design of steel parts, 368*A*.

PARDUN, C., on centrifugal castings, 320*A*.

PARKER, W., on normalising of sheet steel, 356*A*.

PARKER, W. H., on wear of tyre chains, 409*A*.

PARR, S. W., on classification of coal, 259*A*.

—— on embrittlement of boiler plate, 435*A*.

PARRISH, P., on ammonia recovery, 277*A*.

PARTRIDGE, J. H., on magnetic and electrical properties of cast iron, 425*A*.

PATCHELL, W. H., on boiler practice, 251*A*.

PATON, N. A., elected member, 11.

PATTERSON, W. S., on corrosion of galvanised steel, 441*A*.

PEACE, A. E., on malleable castings, 323*A*.

PEARCE, J. G.—

      Paper on " The Use and Interpretation of the Transverse Test for Cast Iron," 73.—*Discussion*, 91.—*Correspondence*, 100.—*Author's Reply*, 103.

—— on tests of cast iron, 383*A*.

—— on test-bars for grey cast iron, 383*A*.

PEASE, C. E., elected member, 11.

Q.

R.

U.

V.

W.